

A MULTIPLE MICRO-PULSE
GENERATOR

John W. Rhinesmith

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JOHN W. RHINESMITH

By:

Lt. John W. Rhinesmith, USN
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Thesis

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A MULTIPLE MICRO-PULSE GENERATOR

By:

Dr. John R. Hoffmann, JR.

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FOREWORD

This report describes in some detail the work performed by the author during a thirteen week period extending from 2 January 1952 to about 29 March 1952. It is submitted in partial fulfillment of the requirements of the Engineering Electronics course at the U. S. Naval Postgraduate School, Monterey, California.

The experimentation was carried out at Melpar, Inc. in Alexandria, Virginia.

The report is in a summary format rather than a chronological one. It includes considerable engineering and product detail in order to assist those who may use the unit built, or who may undertake construction of similar units in the future at Melpar.

In the laboratories of this firm there was, at this time, the need for a multiple pulse generator for use in the general development of pulse time modulated equipments. In the course of design of these pulse time modulated equipments, testing was involved which required short S-band r-f pulses. A TS-155C r-f signal generator was modified to furnish these test signals. The TS-155C signal generator itself, however, had to be modulated by a series of very narrow pulses with rise times of the order of a tenth of a microsecond. These pulses were required to be capable of being positioned, in time, as close together as six-tenths of a microsecond, and furthermore they were to be capable, either singly or severally, of being wobbled at audio frequencies (20 to 3000 cycles per second) up to 1.0 microsecond either side of their normal positions.

INTRODUCTION

This report describes in some detail the work performed by the author during a thirteen week period extending from 5 January 1952 to about 29 March 1952. It is submitted in partial fulfillment of the requirements of the Engineering Electronics course at the U. S. Naval Postgraduate School, Monterey, California. The experimentation was carried out at Naval, Inc. in Alexandria, Virginia.

The report is in a summary format rather than a chronological one. It includes considerable engineering and product detail in order to assist those who may use the unit built, or who may undertake construction of similar units in the future at Naval. In the laboratories of this firm there was, at this time, the need for a multiple pulse generator for use in the general development of pulse time modulated equipments. In the course of design of these pulse time modulated equipments, testing was involved which required about 2-band x-1 pulses. A 25-1550 x-1 signal generator was modified to furnish these test signals. The 25-1550 signal generator itself, however, had to be modulated by a series of very narrow pulses with rise times of the order of a tenth of a microsecond. These pulses were required to be capable of being positioned, in time, as close together as six-tenths of a microsecond, and furthermore they were to be capable of either singly or serially, of being modulated at audio frequencies (20 to 2000 cycles per second) up to 1.0 microsecond either side of

The need for such a multiple pulse generator, or modulator, is the justification for the time and effort expended in its design and construction.

Every courtesy, facility, and encouragement was extended by those who were my associates at Melpar. For this I am extremely grateful.

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John W. Hammond

INTRODUCTION

The design and testing of the pulse time modulated units, mentioned in the foreword required a laboratory layout of considerable flexibility. Both the r-f signal generator and the multiple pulse generator used to modulate it had to meet rather severe requirements as reference to their outputs.

There were not available, commercially, any S-band r-f signal generators capable of being pulsed satisfactorily at such close intervals as the .6 microsecond spacing required. This presented the possibility of either modifying an r-f generator, such as the TS-155C, or of building a new unit employing a pulser tube and cavity that could be triggered at the required time intervals.

Another problem now appeared. This was the question of what to use as a modulator for the r-f generator referred to above. This modulator or pulse generator had to meet the following needs:

It must generate a train of at least five pulses.

These pulses must not be greater than .2 microsecond in width at their 50% amplitude points.

The rise time of an individual pulse must not exceed .1 microsecond.

The individual pulse must not contain a transient that will interfere with a following pulse, when spaced as closely as .6 microsecond (leading edge to leading edge).

The pulses must be of sufficient amplitude to fire the r-f generator which the unit is to modulate.

INTRODUCTION

The design and testing of the pulse time modulated units, mentioned in the foregoing report, a laboratory layout of considerable flexibility. Both the r-f signal generator and the multiple pulse generator used to modulate it had to meet rather severe requirements as reference to their outputs.

There were not available, commercially, and 2-band r-f signal generators capable of being pulsed satisfactorily at such close intervals as the 6 microsecond spacing required. This presented the possibility of either modifying an r-f generator, such as the TS-1520, or of building a new unit employing a pulser tube and cavity that could be triggered at the required time intervals.

Another problem now appeared. This was the question of what to use as a modulator for the r-f generator referred to above. This modulator or pulse generator had to meet the following needs:

It must generate a train of at least five pulses. These pulses must not be greater than 5 microsecond in width at their 50% amplitude points.

The rise time of an individual pulse must not exceed 1 microsecond.

The individual pulse must not contain a maximum that will interfere with a following pulse, when spaced as closely as 6 microsecond (leading edge to leading edge).

The pulses must be of sufficient amplitude to drive the r-f generator which was used in the foregoing.

Each pulse must be capable of being positioned or delayed over a period of at least 0 to 3 microseconds.

Any selected pulse or pulses must be capable of being modulated, in time, sinusoidally at a frequency of 20-3000 cycles per second, with an excursion up to 1.0 microsecond either side of the initial position.

Finally, there must be no cross talk between pulses in the output train.

To meet these requirements, the pulse generator or modulator described in this paper was evolved.

In order that the design and construction of this piece of test equipment might follow a logical and orderly sequence the unit was broken down into ten sections, or so called channels (see drawing EAl).

Channel (A) is a free running blocking oscillator with a control for adjusting the pulse repetition rate. The output pulses from this channel control channels (B) and (C).

Channel (B) is composed of a delay multivibrator and slave blocking oscillator. The output is a positive pulse which can be delayed by adjusting the recovery time of the delay multivibrator.

Channel (C) contains a delay multivibrator, a clipping and stretching pulse shaping network, an audio amplifier and a slave blocking oscillator. A fixed d-c potential, a positive pulse with a stretched leading edge, and an audio frequency sine wave are combined in the grid circuit of the slave blocking oscillator. This combination produces a varying bias which controls the time of firing of the blocking oscillator. The output of channel (C) is a positive going pulse which is wobulating at the same audio frequency as that audio signal on the grid.

Each pulse must be capable of being sustained or delayed over a

period of at least 0 to 3 microseconds.

Any selected pulse or pulses must be capable of being modulated,

in time, sinusoidally at a frequency of 30-3000 cycles per second, with

an excursion up to 1.0 microsecond either side of the initial position.

Finally, there must be no cross talk between pulses in the output

train.

To meet these requirements, the pulse generator or modulator de-

scribed in this paper was evolved.

In order that the design and construction of this piece of test

equipment might follow a logical and orderly sequence the unit was

broken down into ten sections, or so called channels (see drawing WAF).

Channel (A) is a free running blocking oscillator with a control

for adjusting the pulse repetition rate. The output pulses from this

channel control channels (1) and (5).

Channel (2) is composed of a delay amplifier and a slave block-

ing oscillator. The output is a positive pulse which can be delayed by

adjusting the recovery time of the delay amplifier.

Channel (3) contains a delay amplifier, a clipping and stretch-

ing pulse shaping network, an audio amplifier and a slave blocking oscil-

lator. A fixed 3-c blocking oscillator, a delay amplifier and a selected leading

edge, and an audio amplifier are incorporated in the slave circuit

to produce a selected leading edge pulse which can be delayed by

adjusting the recovery time of the delay amplifier.

Channel (4) is a free running blocking oscillator with a control

for adjusting the pulse repetition rate.

The outputs of these two channels (B) and (C) are connected individually to the contacts of a bank of five single pole double throw switches. Each of these switches selects the pulse, fixed or wobulated, to be used to control a separate pulse generation channel, similar in circuitry to channel (B). These five channels are labeled (D) through (H).

As has been indicated, each of the channels (D) through (H) produces a single positive output pulse. This pulse is either stationary or wobulating depending on the pulse selected by the selector switch to control the channel.

The five pulses generated by these channels then are combined in the mixing channel (K). The output of this channel is either a positive or a negative pulse train which can be coded as explained above.

The remaining section, designated Channel J, is the regulated power supply.

A complete block diagram showing the individual stages within the channels is included as drawing EA2. In the following pages, a detailed description of the functions of the channels is given. The channels are treated individually. The description of the action in the final or mixing channel is quite extended and shows clearly that the output from this channel meets the pulse train requirements stated previously, and that the unit, when finally built and tested, constitutes a satisfactory source of pulses with the characteristics and requirements set forth earlier in this introduction.

The outputs of these two channels (4) and (5) are connected indi-

vidually to the contacts of a bank of five single pole double throw switches. Each of these switches selects the pulse, fixed or wobbling, to be used to control a separate pulse generation channel, either in channel (6) or channel (7). These five channels are labeled (A) through (E). (H).

As has been indicated, each of the channels (A) through (H) produces a single positive output pulse. This pulse is either stationary or wobbling depending on the pulse selected by the selector switch to control the channel.

The five pulses generated by these channels are then combined in the mixer channel (H). The output of this channel is either a positive or a negative pulse train which can be used as explained above. The remaining section, designated channel 9, is the related power supply.

A complete block diagram showing the total system within the channels is included as drawing 100. In this diagram, a detailed description of the function of the channels is given. The channels are divided into three main sections. The first section is the pulse generation section, which produces the positive and negative pulses. The second section is the pulse selection section, which selects the pulse to be used to control the pulse generation channel. The third section is the pulse combination section, which combines the five pulses into a single pulse train. The output of this section is the pulse train which can be used as explained above.

Detailed Description of Channels:

Channel A. FREE RUNNING BLOCKING OSCILLATOR

This channel is composed of a single stage, 65670, a high reliability, high frequency twin triode. Referring to drawing EA3, the triode is operated as a free running blocking oscillator, and is used as the master oscillator or timing reference for the entire unit. The pulses produced by this stage are very narrow, about .2 microsecond, and their frequency can be controlled. R_5 , which is a 5 megohm potentiometer front panel control and C_5 , a 100 micromicrofarad capacitor, determine the pulse repetition frequency. R_{26} , a 5.1 K resistor, is for the purpose of limiting the small grid current which tends to flow just before the tube blocks. The damping resistor R_{24} , 2.7 K, is used in the grid circuit to limit, somewhat, the overshoot after blocking occurs.

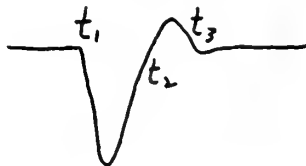


Plate waveform

Referring to the above sketch of the pulse waveform at the plate of the oscillator tube, the damping action is as follows:

Prior to t_1 the tube is in a cutoff state and the plate rides at B_+ , or about 260 volts positive. At t_1 , the grid has recovered sufficient to bring the tube out of cutoff and into the conduction region. The plate potential then drops and the grid potential rises very rapidly due to the regenerative action of the pulse transformer. During this period, t_1 to t_2 , the damping resistance, reflected into

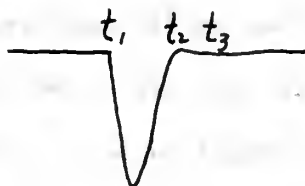
Details of the results of the survey:

CHARTERED A. THE NATIONAL ASSOCIATION OF

This channel is composed of a single stage, 6507, a high reliability, high frequency twin triode. Referring to drawing H-1, the triode is connected as a free running blocking oscillator, and is used as the master oscillator or timing reference for the entire unit. The pulses produced by this stage are very narrow, about 2 micro-seconds, and their frequency can be controlled. G₁, which is a 2 megohm potentiometer, front panel control and G₂, a 100 ohm potentiometer, are used to control the pulse repetition frequency. H₁ is a 100 ohm potentiometer, is for the purpose of limiting the small grid current which tends to flow just before the blocking. The damping resistor R₁, 500 ohms, is used in the grid circuit to limit, somewhat, the overshoot after blocking occurs.

the plate circuit as an impedance of the same value, due to the 1:1 turns ratio of the windings, is in parallel with the small dynamic plate resistance of the tube. The damping resistance then has only a small effect on the total swing of the plate and so attenuates the pulse amplitude only slightly.

During time t_2 to t_3 , however, the situation is considerably modified. At time t_2 the tube is cutoff and the positive swing, or first overshoot, of the plate waveform is developed across the static plate resistance of the tube. As was the case from t_1 to t_2 , this tube impedance, now very much larger than during conduction, is again shunted by the reflected impedance of the small damping resistor. Consequently, the amplitude of the positive swing is greatly reduced with the following output wave at the plate as a result.



By thus reducing the transient to negligible proportions, the pulse repetition rate can be made very high with no cross talk between successive pulses.

The output of the stage is a narrow positive pulse developed across the 100 ohm cathode resistor, R_{25} . It is coupled thru crystals Y_1 and Y_2 , both Raytheon type CK703, to channels (B) and (C) respectively.

the plate circuit as an impedance of the same value, due to the 1:1 turns ratio of the windings, is in parallel with the small dynamic plate resistance of the tube. The damping resistance then has only a small effect on the total value of the plate and so attenuates the pulse amplitude only slightly.

With the following output wave as a result.

Consequently, the amplitude of the positive swing is greatly reduced, shunted by the reflected impedance of the small damping resistor, impedance, now very much lower than during conduction, is again plate resistance of the tube. As was the case from t_1 to t_2 , this tube first overshoot, of the plate waveform is developed across the static load. At time t_3 the tube is cutoff and the positive swing, or during time t_3 to t_4 , however, the situation is considerably



By this means the transient to steady-state response, the pulse repetition rate can be made very high with no great loss between successive pulses.

An interesting feature of the stage is the blocking oscillator transformer. This transformer consists of twelve turns on the primary, and the same number on the secondary, of #38 SSE wire, wound on a mandrel of 3/16" outer diameter. Complete instructions are given on page 48 for winding these coils. The coils are completely contained in a small pot core, see the figure on page which is mounted on a 1-1/8" X 5/8" piece of 3/32" glass silicone board. The electrical properties of this silicone glass laminate are very much superior to those of other types of rigid laminations for electrical applications and, in addition, this type board is characterized by high heat stability and low water absorption. The coil leads are terminated on turret terminal lugs, type 1724C, made by the Cambridge Thermionic Corporation. The turret type lug has two soldering spaces, permitting two or more connections without superimposing wires and assures good contact with neater connections and appearance. The lugs are of brass, heavily silver plated. This type of mounting is a necessity since the #38 wire size is too fine to allow good point to point soldering. The damping resistor is connected between the turret lugs, on which leads F1 and S1 are terminated, affording a sturdy mounting.

The Ferroxcube core employed is made from manganese zinc ferrites, pressed into shape and sintered to give considerable hardness to the element. The material is characterized by high initial permeability, low total losses (residual, eddy current, and hysteresis), high saturation flux density, and good temperature stability. The initial permeability is more than 15 times that of presently available powdered iron cores.

An interesting feature of the stage is the blocking oscillator transformer. This transformer consists of twelve turns on the primary, and the same number on the secondary, of #38, 202 wire, wound on a diameter of 3/16" outer diameter. Complete instructions are given on page 18 for winding these coils. The coils are completely contained in a small pot core, see the figure on page 19 which is mounted on a 1-1/8" x 5/8" slot of 3/32" glass silicone board. The electrical properties of this silicone glass laminates are very much superior to those of other types of rigid laminates for electrical applications and, in addition, this type board is characterized by high heat stability and low water absorption. The coil leads are terminated on three terminal lug, type 1734, made by the Cambridge Thermionic Corporation. The three type lug has two soldering spaces, permitting two or more connections without superimposing wires and assures good contact with better connections and resistance. The lugs are of brass, heavily silver plated. This type of mounting is a necessity since the #38 wire size is too fine to allow good point to point soldering. The damping resistor is connected between the three lugs, on which leads 11 and 12 are terminated, affording a sturdy mounting. The thermocouple can be removed if the thermocouple and ferrites, pressed into shape and a metal to the thermocouple laminates to the element. The material is chosen for its high initial permeability, low thermal expansion (thermal, mechanical, and electrical), and low loss. The thermocouple is mounted on the thermocouple element, which is mounted on the thermocouple element.

Above 15 kc the hysteresis losses in a core are negligible in comparison with the eddy current losses. The resistivity of ferroxcube material is so very high that these eddy current losses are very small and any need for laminating the core is eliminated.

The above properties together with the enclosing type core used constitute a very effective pulse transformer. The high Q and permeability permit using a small number of turns, which leads to a very narrow pulse. The waveforms for this stage are shown on page 51.

A sync output is also taken from this section. This is required when the stage is functioning at low pulse repetition rates. Under these conditions, after the tube has blocked, the grid potential approaches cutoff very gradually. As a result there is a considerable range, time wise, over which the tube might again conduct, any slight positive fluctuation in the recovering waveform, as cutoff is neared, being sufficient to cause the tube to again cycle. This results in a very small jitter which can only be overcome by using some means of syncing, such as a sine wave superimposed on the grid, to cause positive firing. However, since the sync output is used to "time control" the rf signal generator which this test unit modulates, the slight jitter effect is not apparent in the pulsed output of that generator.

Shows 15 to the frequency loss in a core are negligible in comparison with the eddy current losses. The resistivity of ferromagnetic material is so very high that these eddy current losses are very small and any

need for laminating the core is eliminated.

The above properties together with the enclosing type core used constitutes a very effective pulse transformer. The high μ and permeability permit using a small number of turns which leads to a very narrow pulse. The waveforms for this stage are shown on page 21.

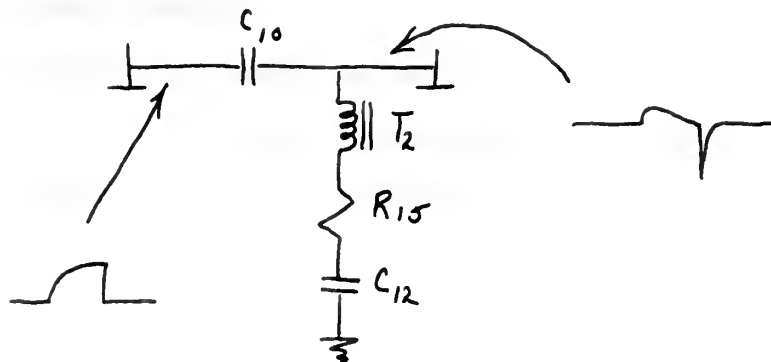
A sync output is also taken from this section. This is required when the stage is functioning as low pulse repetition rates. Under these conditions, after the tube has blocked, the grid potential approaches cutoff very gradually. As a result there is a considerable range, time wise, over which the tube might again conduct, any slight positive fluctuation in the recovering waveform, as cutoff is reached, being sufficient to cause the tube to ignite again. This results in a very small jitter which can only be overcome by using some means of synchronizing, such as a sine wave synchronized on the grid, to cause positive firing. However, since the sync output is used as "sync control" the 12 signal generator which also has a 1000 cycle/sec. oscillator. The jitter effect is not apparent in the output of this generator.

Channel B. DELAY MULTIVIBRATOR & SLAVE BLOCKING OSCILLATOR

This channel generates a positive pulse which can be delayed over a range of several microseconds. Three stages are included in this channel, V_9 and V_{10} the two halves of a 6J6, constituting a one-shot delay multivibrator and V_{11} , a 6C4, a slave blocking oscillator. Referring to figure EA4, action of the circuit is as follows:

A positive pulse from channel (A) is coupled through C_8 to the grid of V_9 . The fixed bias on this grid is such that this positive pulse is sufficient to cause V_9 to conduct. The action that follows is that of a typical one shot multivibrator. The output at the plate of V_{10} is a positive square wave. This wave is not coupled back thru C_7 and C_8 to the cathode of V_{13} because of the unidirectional nature of the crystal, Y_1 , and hence does not interfere with the proper operation of channel (C). The width of this square positive pulse is variable and is controlled by potentiometer R_{30} , a front panel control, in the grid circuit of V_{10} .

The RLC network composed of C_{10} , the plate coil of T_2 , R_{35} and C_{12} differentiates this positive square wave as shown in the accompanying schematic.

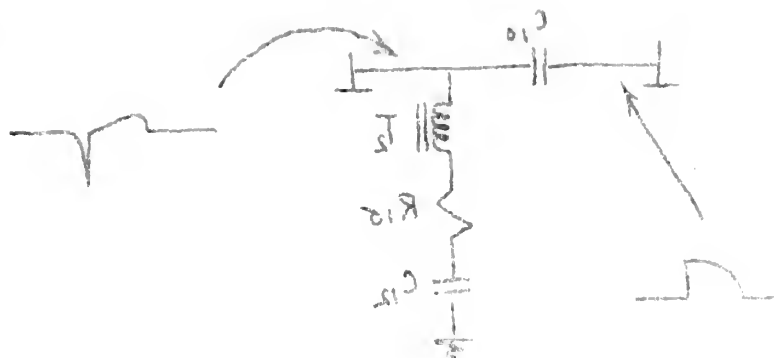


Channel B. DELAY NEUTRALIZER & SLAVE BLOCKING OSCILLATOR

This channel generates a positive pulse which can be delayed over a range of several microseconds. Three stages are included in this channel. V_9 and V_{10} the two halves of a 6BE6, constituting a one-shot delay unit. vibrator and V_{11} a 6BE6, a slave blocking oscillator. Referring to figure B-1, section of the circuit is as follows:

A positive pulse from channel (A) is coupled through C_6 to the grid of V_9 . The fixed bias on this grid is such that this positive pulse is sufficient to cause V_9 to conduct. The action that follows is that of a typical one shot multivibrator. The output at the plate of V_{10} is a positive square wave. This wave is not coupled back thru C_7 and C_8 to the cathode of V_{13} because of the unidirectional nature of the crystal, V_{11} and hence does not interfere with the proper operation of channel (C). The width of this square positive pulse is variable and is controlled by potentiometer R_{10} , a front panel control, in the grid circuit of V_{10} .

The RLC network composed of G_{10} , the plate coil of T_2 , R_{12} and C_{12} differentiates this positive square wave as shown in the accompanying schematic.



The negative spike (the differentiated after edge of the square pulse) serves to initiate action in stage V_{11} , the slave blocking oscillator. This tube is normally held in a non-conducting state by a fixed bias of about -27 volts on its grid. The output of this blocking oscillator is a positive pulse developed across R_{34} , 220 ohm. It is coupled out through a .01 capacitor to C_{13} and may be used to control pulse generation channels (D) through (H).

C_6 , C_{12} , and C_{14} all serve as decoupling capacitors and so prevent modulation of either the B plus or the bias supplies. R_{32} , R_{28} , and R_{29} comprise a voltage divider network from plus 260 volts to minus 42 volts, providing a fixed bias of about -20 volts on the grid of V_9 under dynamic conditions. This keeps the tube well below cutoff and precludes the possibility of the multivibrator free running. This possibility of free running must be avoided since V_{11} will conduct very heavily in the event it occurs. R_{35} is a 1 watt resistor and will burn out quickly when so heavily overloaded. Under normal operation the duty factor is very small since V_{11} conducts only a fraction of a percent of the total time of a cycle and overdissipation in V_{11} and R_{35} is not then a factor for consideration.

Y_3 , a CK708 crystal diode, is used for damping the overshoot in the grid circuit of the blocking oscillator. This method of damping is used in order to obtain the maximum amplitude of output signal. With resistance damping this is not the case.

The waveforms observed at salient points in channel (B) are shown on page 52. Attention is called to that waveform observed at the plate of V_9 . The dotted line, $t_2 - t_3$, shows the expected wave form, the

The negative spike (the differentiated after edge of the square pulse) serves to initiate action in stage VII, the slave blocking oscillator. This tube is normally held in a non-conducting state by a fixed bias of about -25 volts on its grid. The output of this blocking oscillator is a positive pulse developed across R_{11} , 320 ohms. It is coupled out through a .01 capacitor to G_{13} and may be used to control pulse generation channel (B) through (H).

G_{14} , G_{15} , and G_{16} all serve as decoupling capacitors and so prevent modulation of either the B bias or the bias supplies. R_{12} , R_{13} , and R_{14} comprise a voltage divider network from plus 300 volts to minus 150 volts, providing a fixed bias of about -50 volts on the grid of V_9 under dynamic conditions. This keeps the tube well below cutoff and precludes the possibility of the multiplier free running. This possibility of free running must be avoided since V_{11} will conduct very heavily in the event it occurs. R_{15} is a 1 watt resistor and will burn out quickly when so heavily overloaded. Under normal operation the duty factor is very small since V_{11} conducts only a fraction of a percent of the total time of a cycle and overmodulation in V_{11} and R_{15} is not then a factor for consideration.

V_{12} , a 6X4 vacuum tube, is used for damping the overshoot in the grid circuit of the blocking oscillator. This method of damping is used in order to obtain the maximum amplitude of output signal.

For maximum damping this is not possible. The wave form observed at the output of the blocking oscillator (B) and shown in Figure 25. The output of the blocking oscillator is shown in Figure 26. The output of the blocking oscillator is shown in Figure 27.

solid line the observed waveform. The absence of the predicated overshoot is due to the very large shunt capacity between the plate of V9 and ground.

solid line the observed waveform. The absence of the predicted over-
shoot is due to the very large shunt capacity between the plate of Vp
and ground.

Channel C. DELAY MULTIVIBRATOR, STRETCHING & SHAPING NETWORK, SLAVE
BLOCKING OSCILLATOR & AUDIO AMPLIFIER

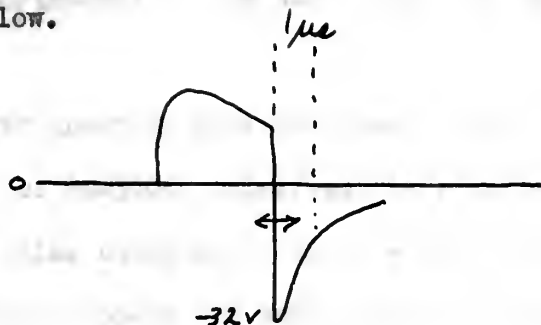
This channel, shown schematically on drawing EA5, produces a pulse about .2 microseconds wide which can be positioned in time over several microseconds and which can be wobbled timewise about one-half microsecond either side of its unmodulated position. The wobulation can be carried out over a frequency range of a few cycles up to several thousand cycles. Over this frequency range and excursion in time the modulation is essentially linear and has no discontinuities. This output pulse is used in the same manner as that from channel (B), to control pulse generation channels (D) through (H).

The entire channel (C) is made up of seven stages. V_1 , and V_2 constitute a variable delay one-shot multivibrator. V_3 is a diode connected triode, 15670 , used for clipping. R_{38} , C_{23} , R_{46} , and R_{49} constitute a pulse stretching and shaping (integrating and peaking) network. V_4 is an inverter - amplifier which is followed by V_5 , an isolation stage cathode follower in which the leading edge of the pulse is further stretched. V_6 is an audio amplifier with low frequency compensation to improve the response of the stage. V_7 is a slave blocking oscillator, normally biased below cutoff, controlled by the combined signals from V_5 and V_6 on its grid.

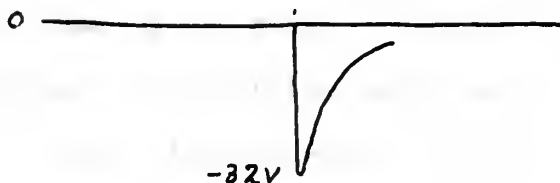
The complete operation of the channel is as follows:

A positive pulse about .2 microseconds wide and 45 volts in amplitude is coupled from channel (A) through C_{15} to the grid of V_1 , the normally OFF section of the delay multivibrator. R_{43} , R_{40} , and R_{39} comprise a voltage divider network which biases V_1 below cutoff with about -30 volts on the grid. The output of the delay multivibrator is

a positive square wave at the plate of V_2 , and the width (position of the trailing edge) of this pulse is controllable by varying R_2 , a 500K potentiometer front panel control. This square wave is differentiated across the $C_{22} - R_{48}$ combination. The diode V_3 passes only the negative pulse obtained from the differentiation of the trailing edge of the square wave. The differentiated pulse as appearing at the cathode of V_3 is shown below.



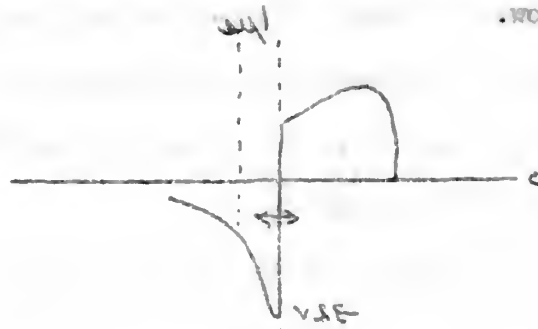
The clipped waveform on the plate of the diode is



The pulse is stretched from .2 microsecond to .4 microsecond by the charging of C_{23} , the stray or shunt capacitance from pin 3 of V_3 to ground. This leading edge is now the important factor for consideration. The negative pulse is developed across the $R_{146} - R_{49}$ combination and a portion of it impressed on the grid of V_4 . In this stage it is inverted and amplified and the leading edge of the plate waveform is stretched to about three microseconds. With a rise time of this duration the early portion is nearly linear. The integrated

a positive square wave at the plate of V_2 , and the width (position of the trailing edge) of this pulse is controlled by varying R_2 , a 500K potentiometer front panel control. This square wave is differentiated across the 0.22 - 10K combination. The diode V_3 passes only the negative pulses obtained from the differentiation of the trailing edge of the square wave. The differentiated pulse as appearing at the cathode of V_3

is shown below.



The clipped waveform on the plate of the diode is



The pulse is generated from a 10K resistor to a 10K resistor by the charging of 0.22. The delay or short capacitance from pin 3 of V_3 to ground. This leading edge is now the important factor for computer-aided. The negative pulse is developed across the 10K - 0.22 combination. It is a portion of it is clipped at the grid of V_4 . In this case it is inverted and amplified and the leading edge of the pulse is now the important factor for computer-aided. The negative pulse is developed across the 10K - 0.22 combination. It is a portion of it is clipped at the grid of V_4 . In this case it is inverted and amplified and the leading edge of the pulse is now the important factor for computer-aided.

wave is coupled via C_{24} to the grid of the cathode follower V_5 . In the cathode follower stage the pulse is further stretched (integrated), a characteristic of such stages. The three microseconds rise time of the pulse on the cathode of V_5 is nearly uniform in its rate of rise. The positive pulse at the cathode of V_5 is coupled through capacitor C_{26} to the grid circuit of the slave blocking oscillator stage, V_7 . This waveform is superimposed on the d-c fixed bias on the control grid of this stage.

An audio input is also provided in this channel. The audio source, a sine wave of 20-3000 cycles/sec, is a Hewlett Packard 202D audio oscillator or similar equipment. V_6 is a low frequency compensated audio amplifier which boosts the audio input in amplitude, after which the signal is coupled through C_{27} to the grid circuit of the slave blocking oscillator. This sine wave form is then superimposed upon the dc fixed bias, also. The three signals (d-c bias, pulse, sine wave) then combine to determine the time at which V_7 will cycle.

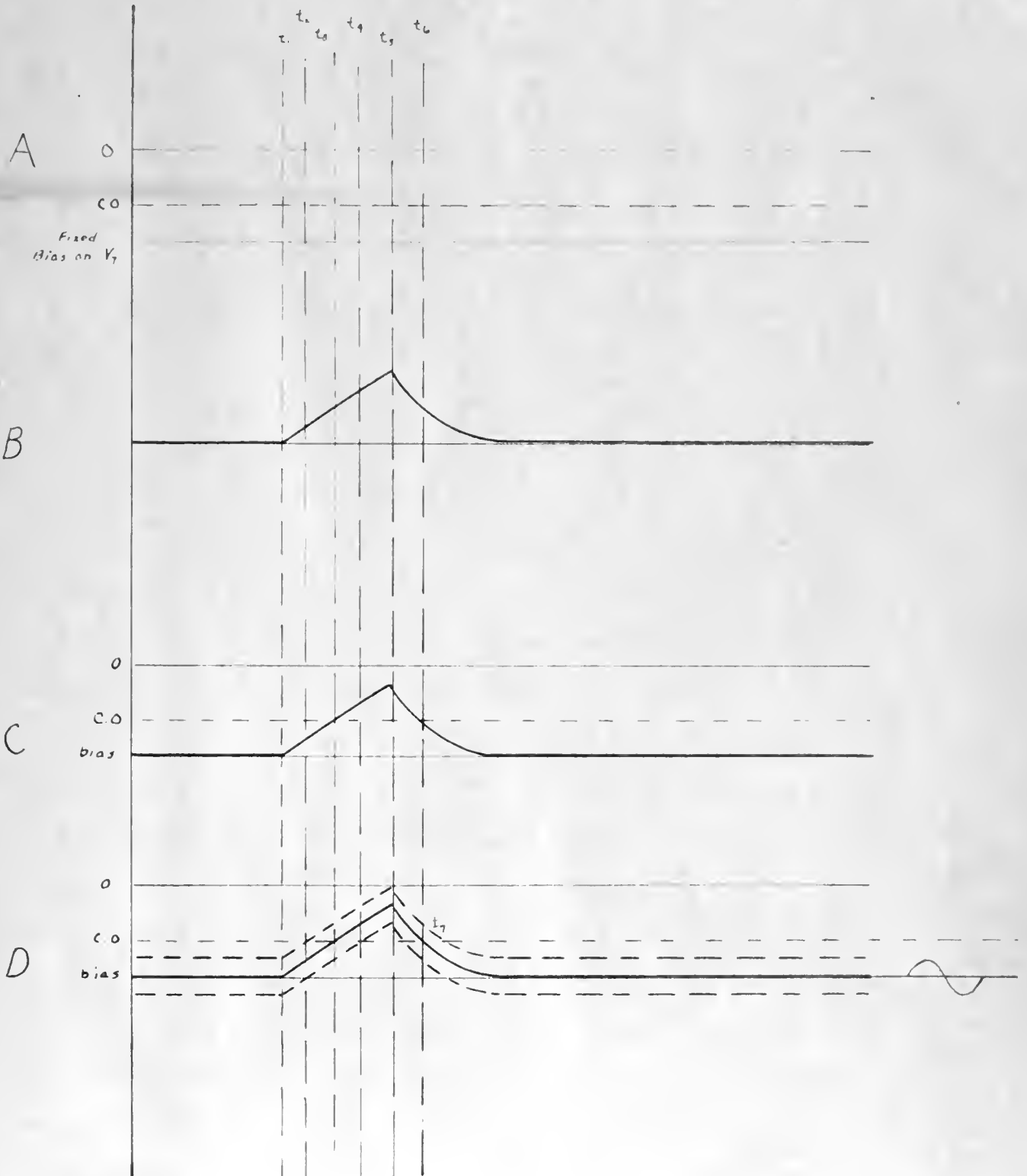
Referring to figure (A) on page 15a, the static conditions are seen to be such that the slave blocking oscillator is biased below cutoff. In this state there is a zero output from the channel. Figure (B) shows the positive pulse with a sloping leading edge which is coupled through C_{26} to the grid circuit of V_7 from V_5 . This pulse combines with the dc bias to give the wave shape of figure (C). Now, it can be seen that at time t_3 the combined signals add to a value which pushes the potential on the grid out of cutoff. At this time, then, the tube conducts, blocks, and completes a cycle with a positive pulse about .2 microsecond wide being developed across R_{47} , the 100 ohm cathode resistor. This pulse and that at the grid are shown on page 53, Waveforms for Channel (C).

wave is coupled via C_{34} to the grid of the cathode follower V_4 . In the
 cathode follower stage the pulse is further stretched (integrated), a
 characteristic of such stages. The three waveforms rise time of the
 pulse on the cathode of V_4 is nearly uniform in its rate of rise. The
 positive pulse at the cathode of V_4 is coupled through capacitor C_{35} to
 the grid circuit of the slave blocking oscillator stage, V_5 . This wave-
 form is superimposed on the d-c fixed bias on the control grid of this
 stage.

An audio input is also provided in this channel. The audio source,
 a sine wave of 30-3000 cycles/sec, is a Hewlett Packard 202D audio oscil-
 later or similar equipment. V_6 is a low frequency compensated audio
 amplifier which boosts the audio input in amplitude, after which the
 signal is coupled through C_{37} to the grid circuit of the slave blocking
 oscillator. This sine wave form is then superimposed upon the d-c fixed
 bias, also. The three signals (d-c bias, pulse, sine wave) when combined
 to determine the time at which V_5 will cycle.

Referring to Figure (A) on page 12, the static conditions are seen
 to be such that the slave blocking oscillator is biased below cutoff.
 In this state there is a zero output in the channel. Figure (B) shows
 the positive bias when a blocking oscillator pulse which is coupled through
 C_{35} to the grid circuit of V_5 from V_4 . This pulse combines with the d-c
 bias to give the wave shape of Figure (C). Now, it can be seen that at
 this time the potential at the grid is a value which makes the potential
 on the grid of the oscillator, in this case, the slave oscillator,

above the cutoff level and the oscillator will begin to oscillate. This
 oscillation is coupled through C_{37} to the grid circuit of the slave blocking
 oscillator, which will then begin to oscillate. This oscillation is coupled



If only the fixed d-c bias of about -20 volts and the positive pulse from V5 were present in the grid circuit of V7, the tube would fire once each time the positive pulse arrive. The recovery time of the stage is sufficient to prevent another cycle being initiated in the time period of t_3 to t_6 when below cutoff conditions are not present. The recovery time actually is such that, at some later time t_7 , a cycle could occur if the grid potential were raised above the cutoff point.

The audio frequency sine wave injected into the grid circuit from the audio amplifier stage V6 modifies the times of firing indicated above. This wave, shown at the right in figure (D), has a frequency very much smaller than that of the positive pulse of figure (B). The d-c fixed bias can be considered to be slowly modulated, toward and away from the cutoff level, by this audio frequency signal. Referring to figure (D), left hand portion, the effect of this sine wave modulation is seen to be on the firing time for the tube V7. As the sine wave increased positively, the firing time is advanced from t_3 to t_2 (upper dotted waveform). When the sine wave swings to its negative extreme the firing time is delayed to time t_4 . Recalling that many positive pulses occur during a single sine wave, the firing time is seen to vary sinusoidally from t_3 to t_2 , back to t_3 , to t_4 , and back again to t_3 during a single audio cycle. The degree of linearity with which this variation of firing time occurs is a function of the uniformity of the slope, or rate of rise, of the leading edge of the positive pulse. Controls R3 (coarse) and R4 (fine) are used to adjust the fixed d-c bias so that firing occurs during the earlier, more linear, portion of the positive pulse's leading edge. Care must be

If only the fixed d-c bias of about -20 volts and the positive pulse from V_g were present in the grid circuit of V_1 , the tube would fire once each time the positive pulse arrives. The recovery time of the stage is sufficient to prevent another cycle being initiated in the time period of t_3 to t_4 when below cutoff conditions are not present. The recovery time actually is such that, at some later time t_7 , a cycle could occur if the grid potential were raised above the cutoff point. The audio frequency sine wave injected into the grid circuit from

the audio amplifier stage V_2 modifies the times of firing indicated above. This wave, shown at the right in figure (D), has a frequency very much smaller than that of the positive pulse of figure (B). The d-c fixed bias can be considered to be slowly modulated, toward and away from the cutoff level, by this audio frequency signal. Referring to figure (D), left hand portion, the effect of this sine wave modulation is seen to be in the firing time for the tube V_1 . As the sine wave increased positively, the firing time is advanced from t_3 to t_2 (upper dotted waveform). When the sine wave returns to its negative extreme the firing time is delayed to t_4 . Recalling that many positive pulses occur during a single sine wave, the firing time is seen to vary sinusoidally from t_2 to t_4 and back again to t_2 during a half sine wave. The degree of intensity with which the variation of firing time occurs is a function of the amplitude of the sine wave.

It is noted that the firing time of the tube V_1 is advanced from t_3 to t_2 when the sine wave is positive and delayed to t_4 when the sine wave is negative. This is the same as the effect of the sine wave on the firing time of the tube V_2 in figure (C). The firing time of the tube V_2 is advanced from t_5 to t_6 when the sine wave is positive and delayed to t_8 when the sine wave is negative.

taken, however, that time t_3 , figure (C), is not advanced so much that t_2 , figure (D), would tend to occur before t_1 . Under such conditions the oscillator would free run and no control would be exercised over the stage during this t_2 to t_1 , period.

The slave blocking oscillator itself is conventional and nearly identical with the one in channel (B). The positive, wobbled, output pulse developed across R_{47} is coupled through C_{20} to a single pole double throw selector switch, where it may be selected to control pulse generation channels (D) through (H).

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Channels (D) through (H). CATHODE FOLLOWER, DELAY MULTIVIBRATOR, SLAVE
BLOCKING OSCILLATOR, CATHODE FOLLOWER

Channels (D), (E), (F), (G), and (H) are identical in circuitry and function. In describing the actions of these channels reference will be made only to drawing EA6, Channel (D) of Modulator. For building and identifying components in the other pulse generation channels a cross-reference table is included, see pages 46 and 47.

Action in pulse generation channel (D) is inaugurated by a fixed positive pulse selected from channel (B) by switch S_3 , or by a positive pulse wobbled timewise at an audio frequency selected from Channel (C) by the same switch, S_3 . This positive pulse, fixed or wobbled, is coupled through isolation cathode follower V_{43} to the grid of V_{14} , the normally OFF half of the variable delay multivibrator V_{14} - V_{15} . The grid of V_{14} is maintained below cutoff potential by a fixed d-c bias of -27 volts.

The output of this multivibrator is a positive square pulse appearing at the plate of V_{15} . The width of this pulse, i.e. the after edge, is variable using potentiometer R_7 on the front panel. This square wave is differentiated in the circuit of C_{48} and the plate coil of T_4 . The negative pulse, resulting from differentiating the after edge causes the slave blocking oscillator to cycle. A positive pulse, .2 microsecond wide, is developed across the 100 ohm cathode resistor, R_{84} . This signal is coupled through a cathode follower, V_{17} for purposes of isolation, and thence to crystal diode Y_{12} .

Crawford (D) through (H).
DOUGLAS, WILLIAM O., GEORGE FOLLOWS
ALAN H. FOLLOWS, DUTCH FOLLOWS B. DAY, CLAY

Relazione al Parlamento del 1911

and function. In describing the actions of these chemical substances will be made only to a very small extent of the chemical and physical and identifying components in the other units present in chemical and physical substances. The data is in the following table.

1. The following table shows the results of the tests conducted on the various types of lamps used in the tests. The results are given in terms of the number of lamps tested, the number of lamps that failed, and the percentage of lamps that failed.

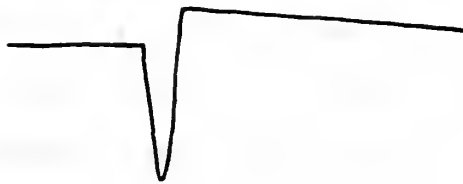
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Channel K. INVERTER AMPLIFIERS AND CATHODE FOLLOWERS

In this, the final channel, the five positive pulses generated in pulse generation channels (D) through (H) are combined, amplified and coupled to BNC output connectors through isolation stages.

Referring now to figure EA7 and the waveforms for channel (K), a series of five pulses is coupled through C_{32} to the control grid of V_{41} , a fairly high g_m , high efficiency power pentode operated as a class A amplifier. This tube is of miniature construction and is characterized by low interelectrode capacitances and high perveance, so is well adapted to high frequency and wide band service. R_{58} and R_{59} form a voltage divider network which provides a fixed bias of -30 volts. By so operating the stage, (fixed bias) the effect of degeneration, present with grid leak or cathode bias, is avoided and greater gain is obtained.

Without some means of limiting, the waveforms at the plate of this stage are as shown below (considering a single pulse):



When several pulses, closely spaced are present, each pulse rides in the combined overshoots of those pulses preceding it and the effect indicated below results:



Channel V. THE FIRST AMPLIFIER AND OUTPUT STAGES

In this, the final channel, the five positive pulses generated in pulse generation channels (1) through (5) are combined, amplified and output to the output connectors through isolation stages.

Referring now to figure 1A, the waveforms for channel (1) a series of five pulses is coupled through G2 to the control grid of V1, a 6X4 vacuum tube. This stage is of class A operation and is characterized by low interelectrode capacitance and high impedance, so as to be adapted to high impedance and wide band amplifier. G2 is a voltage divider network which provides a fixed bias of -30 volts. By so operating the stage, (fixed bias) the effect of leakage current, present with this type of vacuum tube, is avoided and greater gain is obtained.

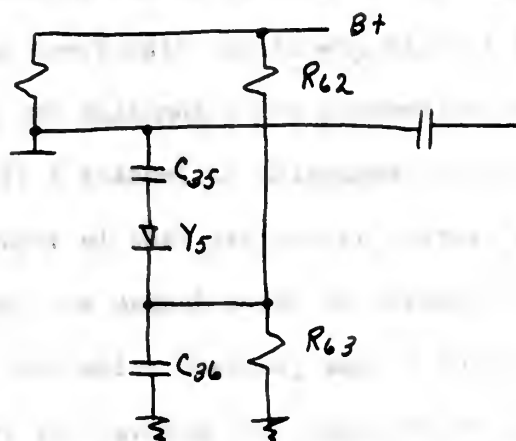
Figure 1B shows some waveforms of channel (1) the waveforms at the plate of this stage are as shown below (considering a single pulse):



The waveforms shown above are typical of the waveforms in the output stage of the first channel. The waveforms in the output stage of the other channels are similar to those shown above.

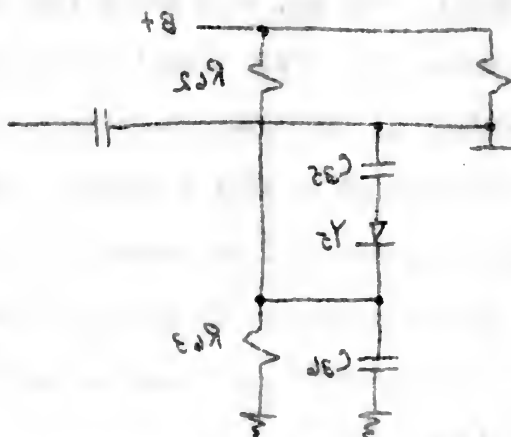


The grid pulses are clean, so the transient is the result of the discharge of stray capacitances in the plate circuit. By using the network below this objectionable effect is eliminated:

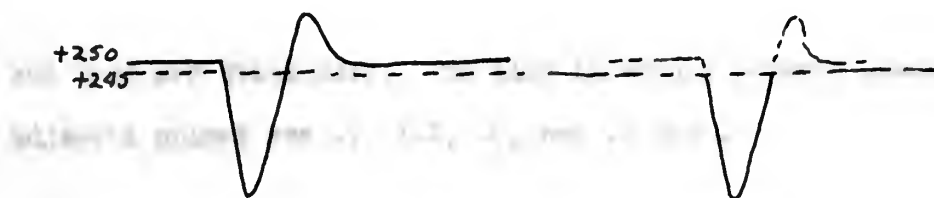


The plate of the tube is normally at about 250 volts. Voltage divider network R_{62} and R_{63} maintains the lower end of the crystal, a CK708, at about 245 volts. The crystal, being a unidirectional device, is arranged so that a positive pulse will be passed from the upper to the lower end (as located in the above drawing). With the circuit elements connected in this manner, whenever the plate of V_{41} is more positive than about 245 volts the crystal presents a low impedance of approximately 350 ohms, and so very effectively clips the overshoot. This is demonstrated in the sketch following:

The grid pulses are clean, so the transient is the result of the discharge of stray capacitance in the plate circuit. By using the network below this objectionable effect is eliminated:



The plate of the tube is normally at about 250 volts. Voltage divider network R_{k2} and R_{k3} maintain the lower end of the crystal, a CKY08, at about 250 volts. The crystal, being a unidirectional device, is arranged so that a positive pulse will be passed from the upper to the lower end (as located in the above drawing). With the circuit elements connected in this manner, whenever the plate of V_{11} is more positive than about 250 volts the crystal presents a low impedance of approximately 250 ohms, and so very effectively clips the overshoot. This is demonstrated in the record following:



Before following the pulses on through the remainder of Channel (K), mention should be made of the flexibility of the pulse train.

As previously explained, each of these five pulses is generated in its own distinct pulse generation channel, channels (D) through (H). If a channel is triggered by the fixed pulse from channel (B), the output of that particular channel will be a fixed pulse. If, instead, the output pulse of channel (C) is used for triggering a pulse generation channel, and if an audio signal is being fed into channel (C) causing its output to be frequency modulated, then the output pulse of that pulse generation channel will also be frequency modulated (wobulated in time).

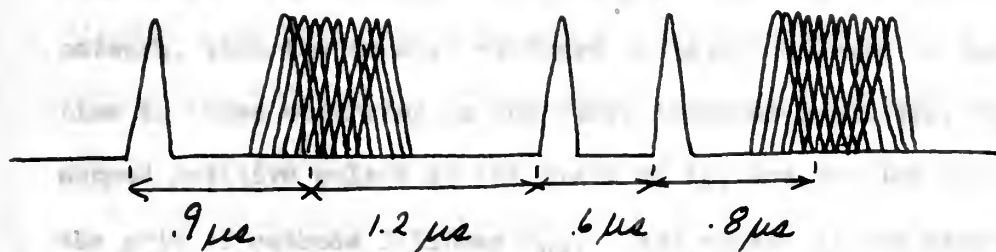
Depending on the position of switches SW_3 through SW_7 , the train of five pulses which is coupled to grid 1 of V_{41} may be constituted of any combination of fixed or wobulated pulses. The pulses may be positioned relative to each other by controls R_7 , R_9 , R_{10} , R_{11} , and R_{12} . Furthermore, all pulses in the train which are produced through action of the trigger pulse from channel (B) can be positioned simultaneously by control R_{30} . The same is true for pulses generated in channels triggered from channel (C), control in time here being effected by R_2 . As an example, in the accompanying figure a typical pulse train is drawn. The second and fifth pulses are shown being wobulated at an audio rate, say 1000 cy/sec. Pulses one, three,



Before following the pulses on through the remainder of Channel (1), mention should be made of the flexibility of the pulse train. As previously explained, each of these five pulses is generated in its own distinct pulse-generation channel, channels (1) through (5). If a channel is triggered by the timed pulse from channel (5), the output of that particular channel will be a fixed pulse. If, instead, the output pulse of channel (5) is used for triggering a pulse-generation channel, and if an audio signal is being fed into channel (5) causing the output to be frequency-modulated, then the output pulse of that pulse-generation channel will also be frequency-modulated (modulated in time).

[illegible]

and four are stationary. The time intervals between leading edges of adjacent pulses are .9, 1.2, .6, and .8 usec.

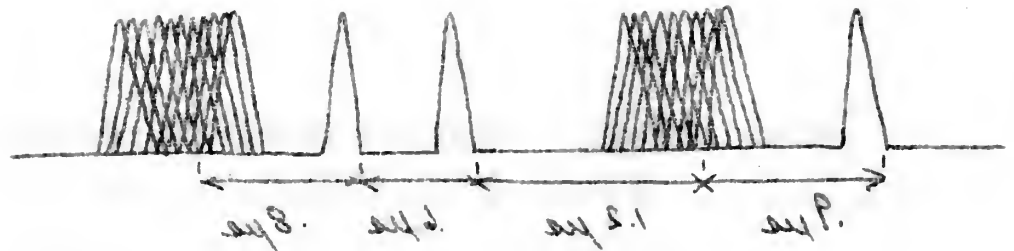


This pulse train is inverted and amplified by V_{41} , shaped by the crystal network and coupled into cathode follower V_{48} for isolation purposes. The pulses on the grid of the cathode follower are negative. If these waveforms are to appear on the cathode of this stage, the grid must be maintained at a positive potential of such magnitude that the tube is not cutoff by the negative input pulses, since this would result in unwanted clipping and distortion of the pulses.

A voltage divider composed of R_{64} and R_{65} furnishes a positive bias of 125 volts under dynamic conditions. This maintains the grid at a proper level to prevent grid clipping. Considerable grid current is drawn, of course, and this injects a grid leak bias into the circuit for consideration. The plus 125 volts desired, and obtained, is the result of fixed plus grid leak bias and, as noted above, is the condition prevailing when the equipment is in operation.

The negative pulse developed across R_{66} is coupled through C_{39} to the BNC fitting on the front panel labeled NEG. OUT. The capacitor C_{39} serves to prevent the tube from burning out in the event a d-c short to ground is placed across the output terminals.

and four are stationary. The time intervals between leading edges of adjacent pulses are 9, 1.5, 0, and 8 msec.



This pulse train is inverted and amplified by V_{11} , shaped by the crystal network and coupled into cathode follower V_{12} for isolation purposes. The pulses on the grid of the cathode follower are negative. If these waveforms are to appear on the anode of this stage, the grid must be maintained at a positive potential of such magnitude that the tube is not cutoff by the negative input pulses, since this would result in unwanted clipping and distortion of the pulses.

A voltage divider composed of R_{11} and R_{12} furnishes a positive bias of 125 volts under dynamic conditions. This maintains the grid at a proper level to prevent grid clipping. Considerable grid current is drawn, of course, and this injects a grid leak bias into the circuit for compensation. The bias (125 volts assumed) and obtained, is the result of fixed bias with leak bias and, as noted above, is the condition prevailing when the equipment is in operation.

A negative pulse applied to the grid of V_{12} is coupled through C_{12} to the grid of V_{13} and V_{14} . The question of the effect of the grid leak bias on the operation of V_{13} and V_{14} is not considered here.

A small portion of the negative pulse appearing at the cathode of V_{48} is coupled to the grid of V_{47} , another 6AN5 inverter-amplifier. This stage is also equipped in the plate circuit with a pulse clipping network, with the crystal reversed to handle signals of opposite polarities to those occurring in the first inverter-amplifier, V_{41} . The shaped positive pulses at the plate of V_{47} are coupled through C_{41} to the grid of cathode follower V_{49} . They appear at the cathode of the same tube and are coupled through a d-c isolation capacitor, C_{40} , to the BNC fitting on the front panel labeled POS. OUT.

A small portion of the negative pulse appearing at the cathode of
 6A8 is coupled to the grid of V_{A7} , another 6A8 inverter-amplifier.
 This stage is also equipped in the plate circuit with a pulse clipping
 network, with the crystal reversed to handle signals of opposite polar-
 ity to those occurring in the first inverter-amplifier, V_{A1} . The
 shaped positive pulses at the plate of V_{A7} are coupled through C_{10} to the
 the grid of cathode follower V_{A9} . They appear at the cathode of the
 same tube and are coupled through a d-c isolation capacitor, C_{11} , to the
 BNC fitting on the front panel labeled POS. OUT.

POWER SUPPLY

The power supply for the subject unit is included as an integral part of that unit. However, the chassis on which it is built can be disconnected from the main chassis merely by breaking the 14 wire connector plug between the two units and removing the fastener bolts holding the two chassis together.

The power supply furnishes plus 260 volts for plate supply and a -42 volt supply for biasing purposes. It also furnishes a filament supply of 6.3 volts, and, although not at present connected to the coupling plug, could furnish a 5 volt filament supply.

The high voltage transformer is a Stancor Universal Type, #P-6314. The plate or secondary furnishes 700 volts, center tapped, at 200 mils. Two filament winding supply 5 volts, center tapped, at 3 amps and 6.3 volts, center tapped, at 5.5 amps. The transformer weighs about 7.7 pounds and has a mounting area of 4.5" X 3.75".

The total filament current drain exceeds the 5.5 amp rating so a separate filament transformer is employed. This transformer is a Stancor Single Secondary Type, #P-6308. The secondary supplies 6.3 v, center tapped, at 10 amps which exceeds somewhat the total filament drain. This filament drain is about 9 amps. The transformer weighs about four pounds and requires a mounting area of 2.8" X 3.2".

Several other equivalent transformers are available commercially and may be substituted if those listed above are unavailable. The P-6314 may be replaced by a Chicago Cat. #PH-200, or U.T.C. Cat. #R-109, or a Thordarson Cat. #T-22R07. The P-6308 has an equivalent in a Chicago Cat. #F-610, a U.T.C. Cat. #CG-122 or an S-61, and a

POWER SUPPLY

The power supply for the subject unit is included as an integral part of that unit. However, the chassis on which it is built can be disconnected from the main chassis merely by breaking the 14 wire connector plug between the two units and removing the fastener bolts holding the two chassis together.

The power supply furnishes plus 250 volts for plate supply and a -15 volt supply for biasing purposes. It also furnishes a filament supply of 6.3 volts, and, although not at present connected to the coupling plug, could furnish a 5 volt filament supply.

The high voltage transformer is a General Universal type, #9-5314. The plate or secondary furnishes 700 volts, center tapped, at 200 ma. Two filament windings supply 5 volts, center tapped, at 3 amps and 6.3 volts, center tapped, at 2.5 amps. The transformer weighs about 7.7 pounds and has a mounting area of 4.5" X 3.75".

The total filament current drain exceeds the 2.5 amp rating so a separate filament transformer is required. This transformer is a General Single Secondary type, #9-1303. The secondary supplies 6.3 v. center tapped, at 10 amps which exceeds the total filament drain. The transformer weighs about 3.5 pounds and has a mounting area of 3.5" X 2.5".

Several other equivalent transformers are available commercially and may be used when it would be more desirable. The transformer is connected to a 115-0-115 volt, 60 cycle, AC line. The transformer is connected to a 115-0-115 volt, 60 cycle, AC line. The transformer is connected to a 115-0-115 volt, 60 cycle, AC line.

Thordarson Cat. #T-21F12.

For rectification, three 6X4 full wave rectifiers are connected in parallel. These miniature tubes have a max. dc output current handling capacity of 70 ma a piece or 210 ma for the parallel combination.

A pi type C-L-C smoothing filter is employed. The capacitors used are 40 microfarad, plug in type (using octal socket) electrolytics, rated at 450 working volts.

The single filter choke in the network is a Stancor Heavy Duty Type, #C-1721, 8.5 henries and rated at 200 ma. Its d-c resistance is 120 ohms, weight about 4 pounds and mounting dimensions 3.2" x 3.3". Other commercial equivalents are Chicago Cat. #RC-8200 and Thordaraon Cat. #T-20C55, 56.

A 6AS7G, low mu twin power triode is used as a current control tube. This glass octal tube is the only non-miniature employed in the entire unit. The current handling capacity is 125 ma per section. The bias control tube is a 6AK5 sharp cutoff pentode. An OA2 glow-discharge diode is used, for a 150 volt voltage regulator. A divider network, R₁₅ and R₈, provides bias control for the 6AK5. The positive and negative output voltages are taken off across R₁₈ and R₂₀ respectively, a bleeder network.

In detail the regulated power supply functions as follows:

The 115 volt ac input voltage is stepped up by T₉ to 700 volts. The secondary is center tapped so that 350 volts (rms) is applied across each section of the full wave rectifiers. The two halves of the rectifiers conduct alternately as each plate is made positive by the secondary of the transformer. The capacitors C₁ and C₂ charge

Thorndson Cat. 4T-2121R.

For rectification, three 6X4 full wave rectifiers are connected in parallel. These miniature tubes have a max. dc output current handling capacity of 70 ma a piece or 210 ma for the parallel combination.

A pi type C-L-C smoothing filter is employed. The capacitors used are 40 microfarad, 500 vdc (min. actual socket) electrolytics, rated at 150 working volts.

The single filter choke in the network is a Stancor heavy duty Type C-1721, 6.5 henries and rated at 200 ma. Its d-c resistance is 150 ohms, weight about 4 pounds and mounting dimensions 3.5" x 3.3".

Other component equivalents are Chicago Cat. 4TC-8200 and Thorndson Cat. 4T-20025, 50.

A 6AS7, low mu twin power triode is used as a current control tube. This less output tube is the only non-miniature employed in the output stage. The current limiting capacity is 150 ma per section. The bias control tube is a 6AR5 sharp cutoff pentode. An OAS glow-discharge diode is used, for a 150 volt reference resistor. A divider network, R17 and R18, provides bias control for the 6AS7. The positive and negative output voltages are taken off across R18 and R19 respectively.

A bleeder network.

In detail the regulated power supply functions as follows:
The 115 volt ac input voltage is stepped up by 10 to 700 volts. The secondary is connected to the 115 volt (115) is applied to the primary of the power transformer. The two halves of the secondary are connected to the 6AR5 and 6AS7 respectively. The positive and negative output voltages are taken off across R18 and R19 respectively.

when the rectifiers conduct and discharge through the bleeder network when the tube is not conducting. The choke tends to keep a constant current flowing in the same direction through the load, due to the build-up and collapse of its magnetic field when the current increases and decreases.

The voltage (d-c) at the positive end of C_1 is 400 volts when the equipment is in full operation. The potential across C_2 is 375 volts. This means a drop of 25 volts occurring across the choke, L_1 .

The current being drawn is then

$$25v/120 \text{ ohms} = 208 \text{ ma.}$$

This current is divided three ways between the 6X4's, i.e. 69 ma per tube. The drop across the rectifiers is

$$69 \text{ ma} \times 150 \text{ ohms} = 10.4 \text{ volts.}$$

The 150 ohms is the approximate total effective plate supply impedance per plate for the rectifiers.

The capacitor input to the filter is used to obtain a somewhat higher output voltage. The output voltages of the regulator are developed across the bleeder network R_{18} and R_{20} in parallel with the R_{15} - R_8 . R_{18} is also paralleled by the resistance of the load. All the load current must also flow through the plate to cathode resistance of V_{38} , the current control tube. All the other elements in the regulator circuit function to control this resistance of V_{38} and thereby maintain a constant load voltage.

The plate supply voltage of V_{39} is the regulated output, i.e. about 260 volts with respect to ground (or 302 volts with respect to the center tap of the secondary).

when the rectifier conduct and discharge through the bleeder network when the tube is not conducting. The choke tends to keep a constant current flowing in the same direction through the load, due to the build-up and collapse of the magnetic field when the current increases and decreases.

The voltage (4-5) at the positive end of C_1 is 400 volts when the equipment is in full operation. The potential across C_2 is 375 volts. This means a drop of 25 volts occurring across the choke L_1 .

The current being drawn is then

$$375/120 \text{ ohms} = 3.125 \text{ ma.}$$

This current is divided three ways between the C_1 's, i.e. 62 ma

per tube. The drop across the rectifier is

$$62 \text{ ma} \times 150 \text{ ohms} = 9.3 \text{ volts.}$$

The 150 ohms is the approximate total effective plate supply

impedance per plate for the rectifiers.

The capacitor C_2 is used to filter the output of the rectifier.

higher end of voltage. The output voltage of the rectifier are de-

veloped across the bleeder network R_1 and R_2 in parallel with the

load. All the R_1 and R_2 in parallel with the resistance of the load. All the

load current must also flow through the plates to overcome resistance of

V_{p1} , the current control valve. All the other elements in the network

for circuit (Fig. 1) is connected to ground. The resistance of R_1 and R_2 are

also a constant load voltage.

The plate supply voltage is 400 volts. The output voltage is 375 volts.

The output voltage is 375 volts. The output voltage is 375 volts.

The output voltage is 375 volts. The output voltage is 375 volts.

The bias on V_{39} is set by R_8 and so controls the current flow through the 6AK5. This current flows through R_{13} , an 82K plate resistor, causing a drop across it. This drop is the bias on V_{38} . Hence, the adjustment of R_8 establishes the normal plate resistance of V_1 . This adjustment is used to set the desired value of load voltage which the regulator is to maintain, in this case plus 260 volts.

Any tendency for the load or output voltage to drop tends to increase the bias on V_{39} . This results directly in a lower bias for V_{38} , which in turn means a lowering of the plate resistance of this tube. A smaller portion of the available voltage then appears across the tube and so the output load voltage remains practically constant.

The pentode is used for V_{39} because small variations in the load voltage are amplified sufficiently to insure proper operation of the regulator circuit.

To insure that the glow tube V_{34} will ionize when the power supply is first turned on its anode is connected through R_{14} to the plate of V_{39} .

The bleeder network in this regulator actually serves two purposes. It acts as a discharge path for the capacitors when power is removed, and it acts as a stabilizer to protect the voltage regulator at no load.

The bleeder current is

$$\frac{260v}{11.2K} = 23.2 \text{ ma}$$

which is about 11% of the total current.

Dissipation in R_{18} is

$$(.0232^2) (11200) = 6.3 \text{ watts}$$

The bias on V_{g2} is set by R_2 and so controls the current flow through the diode. This current flows through R_{g1} and the plate resistor, causing a drop across it. This drop in the bias on V_{g1} . Hence, the adjustment of R_2 establishes the normal plate resistance of V_1 . This adjustment is used to set the desired value of load voltage which the regulator is to maintain, in this case plus 200 volts.

Any tendency for the load or output voltage to drop tends to increase the bias on V_{g2} . This results directly in a lower bias for V_{g1} , which in turn means a lowering of the plate resistance of this tube. A smaller portion of the available voltage is then dropped across the tube and so the output load voltage remains practically constant.

The pentode is used for V_{g2} because small variations in the load voltage are amplified sufficiently to insure proper operation of the regulator circuit.

It is further noted that the plate load V_{g1} will increase when the power supply is first turned on the anode is connected directly to the plate of

V_{g2} . The diode circuit in this regulator is usually referred to as a diode circuit. It acts as a diode circuit and the elements which power is converted, and it acts as a stabilizer to prevent the voltage regulator at no load. The circuit diagram is

$$V_{g2} = \frac{V_{g1}}{R_{g1}}$$

where V_{g2} is the bias on V_{g2} and R_{g1} is the plate resistance of V_1 .

The total current flows through R_{20} . Across the resistance, 42 volts is developed, therefore its value is

$$\frac{42\text{v}}{208\text{ ma}} = 202\text{ ohms}$$

A twenty-watt, 500 ohm, wirewound resistor with a variable tap is used here and adjusted to the proper value of 202 ohms.

Plate dissipation in V_{38} is

$$(375 - (260 \text{ plus } 42)) \times .208 = 15.1 \text{ watts}$$

which is slightly above the rated max.

The cutoff or series resonant frequency for one LC section of the filter is

$$f_c = \frac{1}{2\pi\sqrt{LC}} = 8.62 \text{ cy/sec.}$$

The ripple voltage is $E_c \approx f_c^2 / f_o^2$

where $f_o = 120 \text{ cy/sec}$ for a full wave

rectifier. This gives a ripple voltage of $\left[\frac{8.62}{120}\right]^2 = 5.16 \times 10^{-3}$ or the ripple voltage is .516% of the input voltage.

The total current flows through R_{10} through the resistor, -12

value is determined, therefore the value is

$$= \frac{12V}{200 \Omega} = 60 \text{ mA}$$

A twenty-megohm, 500 ohm, wirewound resistor with a variable tap is used

here and adjusted to the proper value of 200 ohms.

Phase displacement is V_{01} is

$$(332 - (150 \text{ plus } 42)) \times 0.006 = 17.1 \text{ volts}$$

which is slightly above the rated value.

The output or a plus terminal frequency for one 12 section of the

filter is

$$f_c = \frac{1}{2\pi \sqrt{LC}} = 6.0 \text{ cycles/sec.}$$

$$\text{The output voltage is } E_o = f_c / f_i$$

$$\text{where } f_i = 150 \text{ cycles/sec. for a full wave}$$

$$\text{rectifier. Then } E_o = \frac{17.1}{150} = 0.114 \text{ or } 11.4\% \text{ on the}$$

ripple voltage is 11.4% of the input voltage.

COMMENTS AND OBSERVATIONS

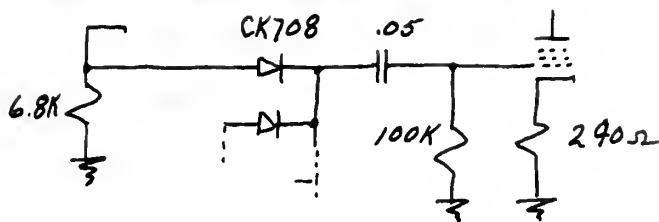
One of the most interesting and more difficult problems encountered in the design of this modulator unit occurred during work on the mixer section, Channel (K).

Clean positive pulses with no visible transients were obtained at the cathodes of V₁₇, V₂₁, V₂₅, V₂₉, and V₃₃ the output cathode follower stages of channels (D), (E), (F), (G), and (H) respectively. These positive going signals were transmitted through the unidirectional crystals Y₁₂ through Y₁₆ (one per channel) and, depending upon the settings of the delay controls in the delay multivibrator in each channel, a coded pulse train was obtained such as that in the accompanying figure,



when observed at the forward end junction of the five CK708 crystals.

The circuit involved was as follows:



The wave shape could be broken down into, say, a stretched pulse with a long decay time plus a transient superimposed on the decaying trailing edge, i.e.

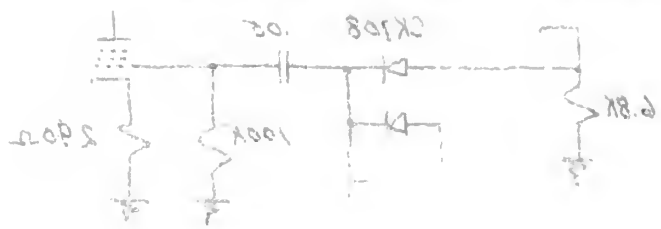
One of the most interesting and most difficult problems encountered in the design of this oscillator was occurred during work on the mixer section, channel (5).

When positive pulses with a stable period rate were applied at the cathodes of V_{17} , V_{21} , V_{22} , and V_{23} the output cathode follower stages of channels (5), (7), (1), and (7) respectively. These positive pulses were applied through the interconnection crystals Y_{10} through Y_{16} (one per channel) and, depending upon the sign of the output controls in the mixer amplifier in each channel, a coded pulse train was obtained such as that in the accompanying

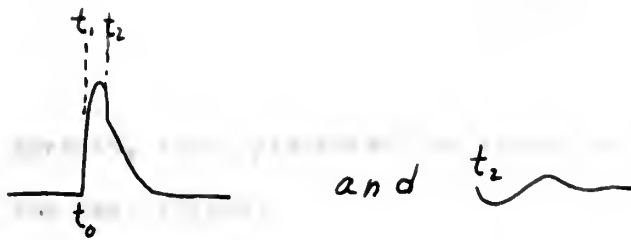
Figure,



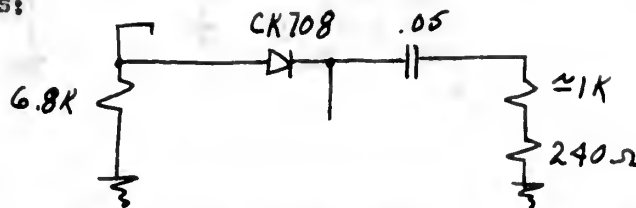
When connected, the forward and reverse of the five (5) crystals. The circuit diagram was as follows:



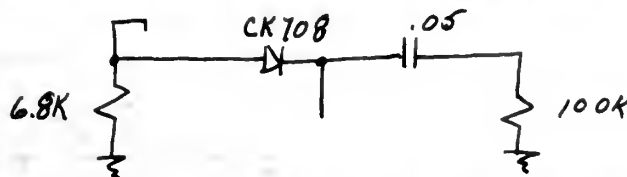
The circuit diagram was as follows:



In the period from t_0 to t_2 the pulse shape was preserved. During the period t_1 to t_2 grid conduction occurred and the equivalent circuit was as follows:



which gave a fairly small RC decay time. However, as soon as the signal fell to where grid conduction ceased, the equivalent circuit became



and the RC was increased over ten fold. The transient which occurred when the abrupt switch from grid conduction to non-conduction took place appeared as a natural result of the lead inductance in series with the coupling capacitance which form a series LC circuit. The high 100K damping resistance in the network prevented it from reaching any sizeable proportions.

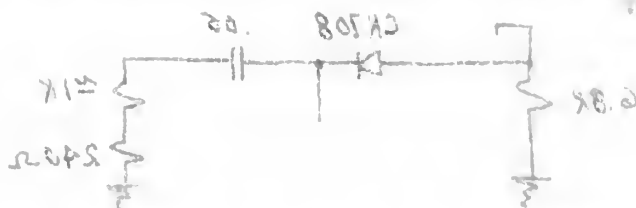
To correct these conditions and so preserve the waveform as developed across the 6.8K cathode resistor, several changes were made.

The long RC time constant was reduced by replacing the .05 capacitor with a .001 and a direct d-c discharge patch (2.2K to ground) included. Fixed bias replaced grid lead bias on the pentode amplifier and all leads were shortened as much as possible.

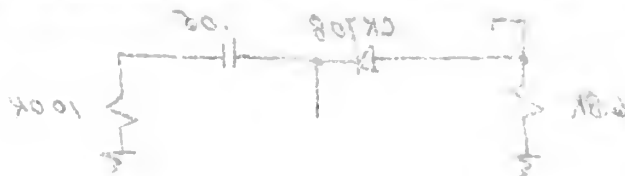


In the period from t_0 to t_1 the pulse height was measured. During the period t_1 to t_2 with connection occurred and the first element

was as follows:



which was a fairly small to each other. However, as soon as the signal fell to zero, the capacitor (0.02) and resistor (240V) circuit became



and the 0.5V was increased over 100V. The first element which occurred when the signal fell to zero, the capacitor (0.02) and resistor (100V) circuit became a pulse generator. The first element which occurred when the signal fell to zero, the capacitor (0.02) and resistor (100V) circuit became a pulse generator. The first element which occurred when the signal fell to zero, the capacitor (0.02) and resistor (100V) circuit became a pulse generator.

In the first case the pulse height was 0.5V and in the second case it was 100V. The pulse height was 0.5V and in the second case it was 100V.

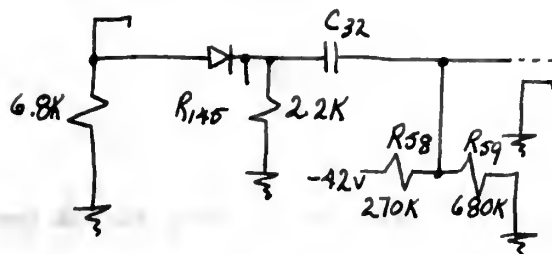
The first case was a pulse height of 0.5V and the second case was 100V.

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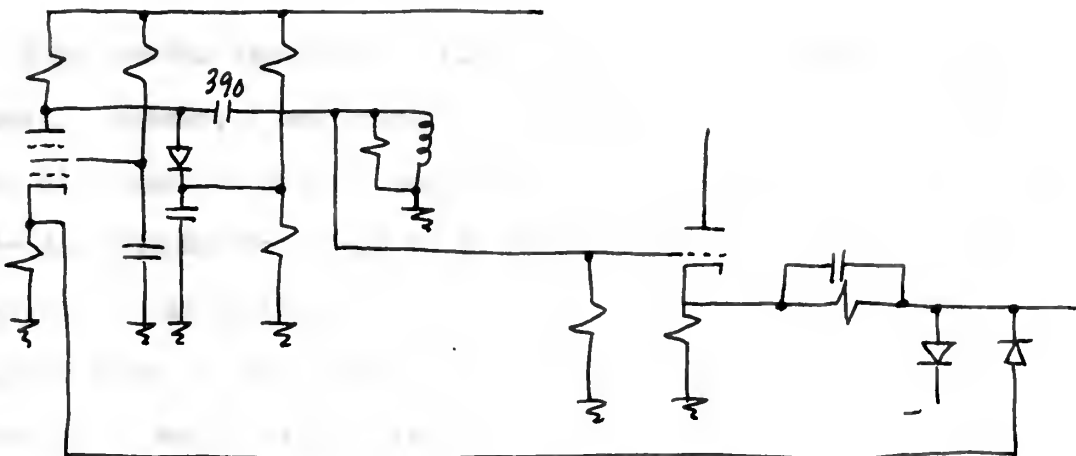
The first case was a pulse height of 0.5V and the second case was 100V.

The first case was a pulse height of 0.5V and the second case was 100V.

The new circuit, which preserved the waveshape very closely was as indicated in the next figure:



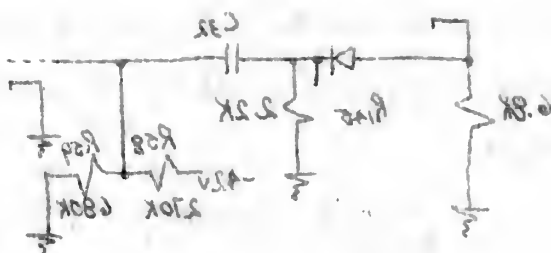
The first plate circuit for V_{41} built up on a breadboard was the following one:



The 390 micromicrofarad coupling capacitor was selected to series resonate with the peaking coil. The damping resistance across this coil was adjusted so that a waveform such as

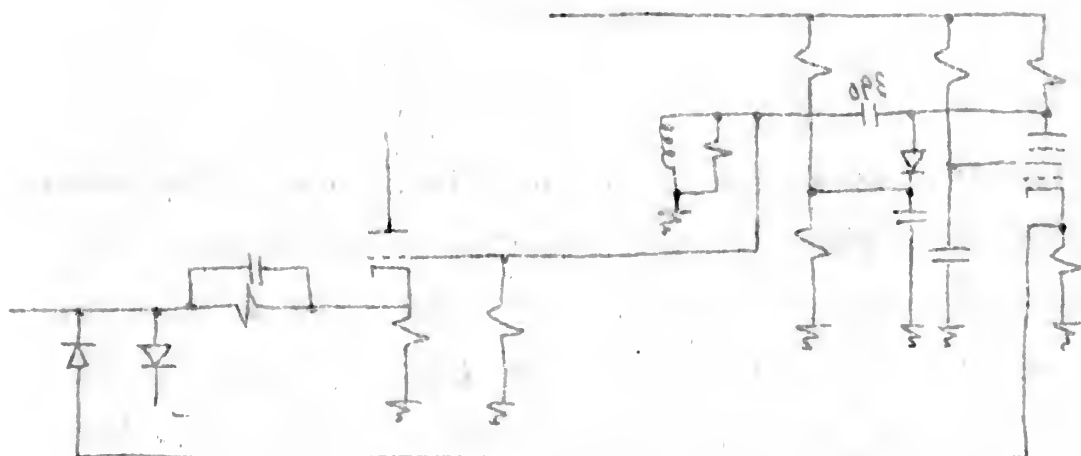
The new circuit, which preserved the wave shape very closely was as

indicated in the next figure:



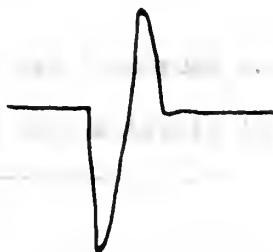
The first phase of the project was to identify the key stakeholders and their interests. This was done through a series of interviews and focus groups. The next phase was to conduct a detailed analysis of the current situation and identify the key issues. This was done through a series of workshops and discussions. The final phase was to develop a strategic plan and implement it. This was done through a series of meetings and reports.

1. What is the purpose of the document?

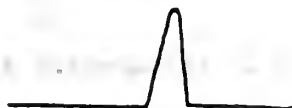
[illegible]

REPORT OF THE COMMISSIONER OF THE GENERAL LAND OFFICE, 1890.

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was obtained at the grid of the cathode follower. With the double limiting network in the output circuit of this cathode follower, a satisfactory positive pulse was obtained.



This was the case when a single pulse was put through the mixing channel. However, a new situation developed when the whole coded train of pulses was coupled through. It was now found that, when one pulse was brought very close to an adjacent one, the positive overshoot, which ultimately becomes the output pulse, rode down into the negative swing of the following pulse and its amplitude was greatly attenuated. And, as all pulses were brought into proximity and the negative swings were compounded, the output pulse train from the cathode follower took on this appearance:

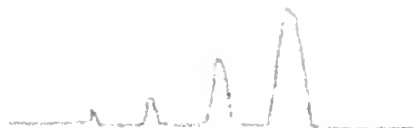




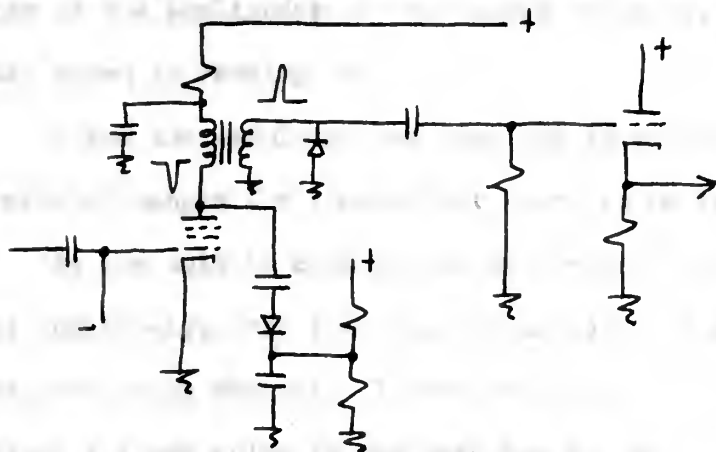
was obtained at the grid of the cathode follower. With the double
 lighting network in the output circuit of this cathode follower, a sat-
 isfactory positive pulse was obtained.



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 channel. However, a new situation developed when the whole coded
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 shoot, which naturally occurs in the output pulse, rode down into the
 negative swing of the following pulse and its amplitude was greatly
 attenuated. And, as all pulses were brought into proximity and the
 negative swings were compounded, the output of the train from the
 cathode follower took on the appearance:

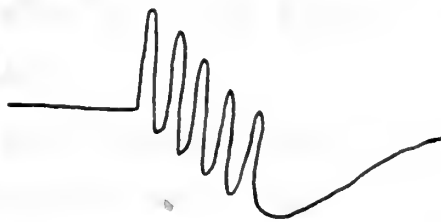


This arrangement was discarded as obviously unsatisfactory and a new circuit, as shown schematically in the next figure, was built:



In this circuit a step-up was obtained in the pulse transformer in the pentode plate circuit. The crystal diode in the secondary clipped any negative overshoot and the crystal network in the primary kept transients from appearing on the pulse developed at the plate of the pentode.

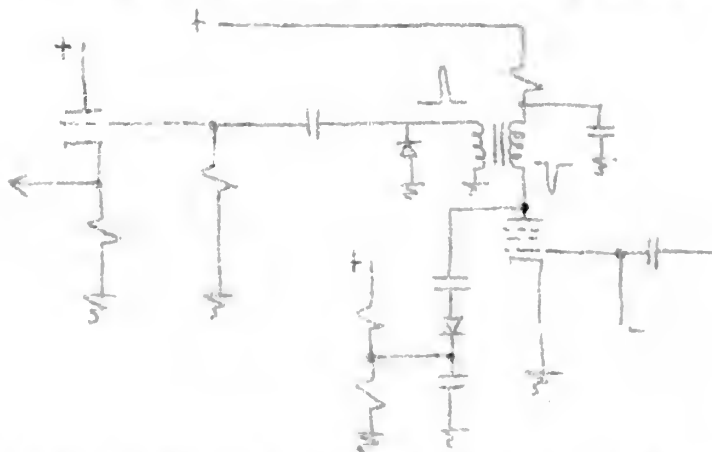
The output pulse train coupled to the cathode follower had the following appearance.



By varying the turns ratio of the pulse transformer, for details of which see drawing EA3, it was found that the remanance of the Ferroxcube core was sufficient, when a step up of 2:1 or greater was employed, that a "following" pulse occurred before the recovery time (of the core) was reached for a "preceding" pulse. Consequently, again there was the problem of one pulse introducing cross-talk upon another. A great many

This arrangement was discarded as obviously unsatisfactory and a

new circuit, as shown schematically in the next figure, was built:



In this circuit a step-up transformer is used in the power transformer in the power supply circuit. The output of the secondary is connected to the primary of the power transformer and the output of the primary is connected to the plate of the

output tube.

The output of the power supply is connected to the cathode of the output tube and the

output of the power supply is connected to the cathode of the output tube.



By varying the input voltage of the power transformer, the output voltage of the power supply can be varied. It was found that the output voltage of the power supply was not very stable, and it was necessary to use a filter capacitor to smooth the output. The output of the power supply was connected to the cathode of the output tube, and the output of the power supply was connected to the cathode of the output tube.

turns ratios, wire sizes, core sizes, etc. were tried before it was found more satisfactory to get away from the cores entirely, due to the size of the amplitudes of the pulses involved. The ultimate circuit is that shown in drawing EA7.

Since the modulator has been completed and has been used, several possible changes for improvement have become apparent.

As the unit is constructed at present there is no means for cutting out completely, from the output coded pulse train, the pulse from any one particular channel. In one position of the single pole double throw switch a fixed pulse is produced and in the other position a wobulating pulse is obtained. By replacing these two position toggles with types incorporating an OFF position, this undesirable condition can be rectified. Due to the circuit location of these switches no snuffer type contact mechanism, for eliminating pitting caused by arcing, is needed. A slow make, slow break type switch will allow decided economies over those switches designed for universal or d-c applications. The General Cement Mfg. Co., is one source of supply for this neutral center switch; Item #1308.

The power supply built for use with this unit utilizes a type 6AS7G as a current regulator in the stabilizing circuit. This is a rather large and unwieldy tube in a unit in which all other tubes are of miniature construction. This 6AS7G envelope protrudes even beyond the transformers and chokes used in the power supply. A new tube very recently brought out by the RCA Victor Division of the Radio Corporation of America is the type 6080. The 6080 is a low-mu, high perveance, twin power triode designed primarily for use as a regulator tube in

turn ratios, wire sizes, core sizes, etc. were tried before it was found core satisfactory to get away from the cores entirely, due to the size of the magnitudes of the losses involved. The ultimate circuit is that shown in drawing 1A.

Since the transformer has been completed and has been used, several possible changes for improvement have become apparent. As the unit is comparatively at present there is no means for cutting out completely, from the output coil pulse train, the pulse from any one particular channel. In the position of the switch pulse double throw switch a fixed pulse in position and in the other position a modulating pulse is obtained. By switching to two position switches with types incorporated in the position, some intermediate condition can be realized. Now as the circuit location of these switches no longer type contact mechanism, the electrical contact caused by moving, in needed. A slow rate, slow pulse rate switch will allow desired frequencies over which may be required for drive and in the application. The General Electric Co., in the design of a high speed motor, has used a switch of this type.

The power supply for the unit will be a 115 volt 60 cycle AC as a current transformer of the unit is required. This is a rather large unit in itself, but it is the only one of its kind in the world. The unit is a 115 volt 60 cycle AC, and it is the only one of its kind in the world. The unit is a 115 volt 60 cycle AC, and it is the only one of its kind in the world.

stabilized d-c power supply units. It is similar to the 6AS7-G in characteristics, but is smaller in size and features conservative ratings.

In d-c amplifier applications, maximum ratings for each unit include a plate voltage of 250 volts, plate current of 125 ma and a plate dissipation of 13 watts. These ratings are identical with those for the 6AS7G.

Another feature which might be changed, and so improve the unit, is the replacement of all 6J6 twin triodes by 5670's. This would reduce the types of tubes employed by one. The two types are similar except that the 6J6 employs a common cathode whereas each section of the 5670 has a separate cathode pin making this tube somewhat more versatile than the 6J6. This change would necessitate some readjustment of component values in the multivibrator circuits where the 6J6 is most frequently utilized.

Along this same line of thought it is noted that the tube V_6 uses $\frac{1}{2}$ 6J6 and the other half of this envelope is unused. Also V_{13} utilizes half of envelope X_{12} while the other half is idle. This offers an opportunity for reducing the tube complement by one.

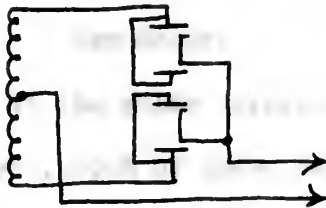
In the power supply the degree of regulation was sufficient to meet requirements of the unit. However, the margin was not great. In order to increase the sensitivity of the regulator to load changes, it may be desirable that a bias control tube, V_{39} , with a greater amplification than that afforded by the 6AK5 should be employed.

One final note about the power supply: It is generally regarded as more satisfactory to use both halves of a rectifier for the same phase and connect them thus,

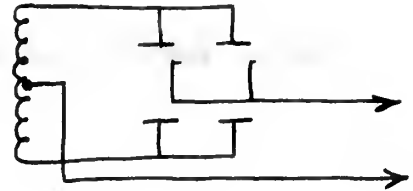
stabilized d-c power supply units. It is similar to the 6AV6-3 in characteristics, but its smaller in size and features conservative ratings. In d-c amplifier applications, maximum ratings for each unit include a plate voltage of 250 volts, plate current of 125 ma and a plate dissipation of 13 watts. These ratings are identical with those for the 6AV6-3. Another feature which might be changed, and so improve the unit, is the replacement of all 6AV6 twin triodes by 6AV6's. This would reduce the types of tubes employed by one. The two types are similar except that the 6AV6 employs a common cathode whereas each section of the 6AV6 has a separate cathode pin which this tube somewhat more versatile than the 6AV6. This change would necessitate some readjustment of component values in the multiplier circuit where the 6AV6 is most frequently utilized. Along this same line of thought it is noted that the tube V_{g2} uses 6AV6 and the other half of this envelope is unused. Also V_{g2} utilizes half of envelope V_{g2} while the other half is idle. This offers an opportunity for reducing the tube complement by one.

In the power supply the degree of regulation is sufficient to meet requirements of the unit. However, the margin was not great. In order to increase the regulation of the regulator to load changes, it may be desirable that a bias control tube, V_{g2} , with a resistor unit-
 attention than was afforded by the V_{g2} should be provided.

The final note about the power supply. It is generally assumed as was satisfactory to use a resistor as a resistor for the same
 these and control are shown.



rather than



However, this requires an even number of rectifier tubes and would involve increasing the tube complement by one.

The CK708 germanium crystal diodes used in numerous circuits throughout the design are a Raytheon product. Their important characteristics are as follows:

Max. d-c inverse voltage	100 v
Peak anode current	100 ma
Max. ave. d-c anode current	35 ma
Min. fwd. current at +1 volt	3 ma
Max. inverse current at -100 volts	.625 ma
Shunt capacitance	1 mmf

There are a number of other germanium diodes available with about the same characteristics. Among these are:

1N38	Sylvania
1N38	Kempton
1N52	General Electric

Germanium when compared with other semi-conductors used in point contact type diodes possesses the following advantages:

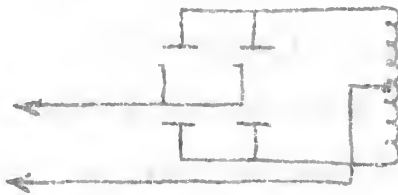
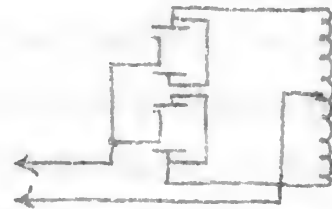


Figure 1



However, this requires an even number of rectifier tubes and would involve increasing the tube complement by one.

The 6X00, a vacuum tube crystal diode used in numerous circuits throughout the design, is a typical product. Their important characteristics are as follows:

100 v	Max. d-c reverse voltage
100 ma	Max. anode current
37 ma	Max. avg. d-c anode current
3 a	Min. tube current at 41 volt
0.02 m	Max. reverse current at -100 volts
1 m	Grid capacitance

There are a number of other vacuum tube diodes available with about the same characteristics. These are:

6X00	100 v
6X01	100 v
6X02	100 v

Other vacuum tube diodes with similar characteristics are:

1. The ability to withstand a much higher inverse voltage.
2. The ability to self-heal in cases where electrical breakdown may occur.

In the pulse transformer applications to which these crystal diodes are put, both of these advantages are an asset.

1. The ability to withstand a much higher inverse voltage.
2. The ability to self-heal in cases where electrical breakdown

may occur.

In the pulse transformer applications to which these crystal diodes

are put, both of these advantages are an asset.

Summary of Front Panel Controls

Type Control	Labeled	Item No.	Function
Pot.	Reg	R ₈	Set regulated voltage
Pot.	Fixed (B)	R ₃₀	Delay Fixed Pulses
Pot.	Wob (C)	R ₂	Delay Wob. Pulses
Pot.	Coarse	R ₃	Adjust bias
Pot.	Fine	R ₄	Adjust bias
Pot.	Rep (A)	R ₅	Control rep. rate
BNC	Sync Out		
Toggle	Fix-Wob	SW ₃	Select Type Pulse
Toggle	Fix-Wob	SW ₄	Select Type Pulse
Toggle	Fix-Wob	SW ₅	Select Type Pulse
Toggle	Fix-Wob	SW ₆	Select Type Pulse
Toggle	Fix-Wob	SW ₇	Select Type Pulse
BNC	Audio-In		
Pot.	Chan. D	R ₇	Delay Pulse
Pot.	Chan. E	R ₉	Delay Pulse
Pot.	Chan. F	R ₁₀	Delay Pulse
Pot.	Chan. G	R ₁₁	Delay Pulse
Pot.	Chan. H	R ₁₂	Delay Pulse
Receptacle	115 v a-c		
Toggle	Fil.	SW ₁	Operate Fil. Xfmr
Toggle	H.V.	SW ₂	Operate H.V. Xfmr
BNC	Neg. Out		
BNC	Pos. Out		

Summary of Front Panel Controls

Function	Term No.	Labeled	Type Control
Set regulated voltage	R8	Reg	Pot.
Delay Fixed Pulses	R30	Fixed (B)	Pot.
Delay Wob. Pulses	R2	Wob (C)	Pot.
Adjust bias	R3	Coarse	Pot.
Adjust bias	R4	Fine	Pot.
Control rep. rate	R7	Rep (A)	Pot.
		Sync Out	Out
Select Type Pulse	SW3	Fix-Wob	Toggle
Select Type Pulse	SW4	Fix-Wob	Toggle
Select Type Pulse	SW5	Fix-Wob	Toggle
Select Type Pulse	SW6	Fix-Wob	Toggle
Select Type Pulse	SW7	Fix-Wob	Toggle
		Audio-In	IN
Delay Pulse	R1	Gen. 1	Pot.
Delay Pulse	R2	Gen. 2	Pot.
Delay Pulse	R3	Gen. 3	Pot.
Delay Pulse	R4	Gen. 4	Pot.
Delay Pulse	R5	Gen. 5	Pot.
		Gen. 6	Pot.
		Gen. 7	Pot.
		Gen. 8	Pot.
		Gen. 9	Pot.
		Gen. 10	Pot.
		Gen. 11	Pot.
		Gen. 12	Pot.
		Gen. 13	Pot.
		Gen. 14	Pot.
		Gen. 15	Pot.
		Gen. 16	Pot.
		Gen. 17	Pot.
		Gen. 18	Pot.
		Gen. 19	Pot.
		Gen. 20	Pot.
		Gen. 21	Pot.
		Gen. 22	Pot.
		Gen. 23	Pot.
		Gen. 24	Pot.
		Gen. 25	Pot.
		Gen. 26	Pot.
		Gen. 27	Pot.
		Gen. 28	Pot.
		Gen. 29	Pot.
		Gen. 30	Pot.
		Gen. 31	Pot.
		Gen. 32	Pot.
		Gen. 33	Pot.
		Gen. 34	Pot.
		Gen. 35	Pot.
		Gen. 36	Pot.
		Gen. 37	Pot.
		Gen. 38	Pot.
		Gen. 39	Pot.
		Gen. 40	Pot.
		Gen. 41	Pot.
		Gen. 42	Pot.
		Gen. 43	Pot.
		Gen. 44	Pot.
		Gen. 45	Pot.
		Gen. 46	Pot.
		Gen. 47	Pot.
		Gen. 48	Pot.
		Gen. 49	Pot.
		Gen. 50	Pot.
		Gen. 51	Pot.
		Gen. 52	Pot.
		Gen. 53	Pot.
		Gen. 54	Pot.
		Gen. 55	Pot.
		Gen. 56	Pot.
		Gen. 57	Pot.
		Gen. 58	Pot.
		Gen. 59	Pot.
		Gen. 60	Pot.
		Gen. 61	Pot.
		Gen. 62	Pot.
		Gen. 63	Pot.
		Gen. 64	Pot.
		Gen. 65	Pot.
		Gen. 66	Pot.
		Gen. 67	Pot.
		Gen. 68	Pot.
		Gen. 69	Pot.
		Gen. 70	Pot.
		Gen. 71	Pot.
		Gen. 72	Pot.
		Gen. 73	Pot.
		Gen. 74	Pot.
		Gen. 75	Pot.
		Gen. 76	Pot.
		Gen. 77	Pot.
		Gen. 78	Pot.
		Gen. 79	Pot.
		Gen. 80	Pot.
		Gen. 81	Pot.
		Gen. 82	Pot.
		Gen. 83	Pot.
		Gen. 84	Pot.
		Gen. 85	Pot.
		Gen. 86	Pot.
		Gen. 87	Pot.
		Gen. 88	Pot.
		Gen. 89	Pot.
		Gen. 90	Pot.
		Gen. 91	Pot.
		Gen. 92	Pot.
		Gen. 93	Pot.
		Gen. 94	Pot.
		Gen. 95	Pot.
		Gen. 96	Pot.
		Gen. 97	Pot.
		Gen. 98	Pot.
		Gen. 99	Pot.
		Gen. 100	Pot.

Vacuum Tube Summary

<u>Tube</u>	<u>Type</u>	<u>Channel</u>	<u>Function</u>
V ₁	1/2 6J6	C	Delay Multivibrator
V ₂ (X ₁)	1/2 6J6	C	Delay Multivibrator
V ₃	1/2 5670	C	Diode Clipper
V ₄ (X ₃)	1/2 5670	C	Inverter-Amplifier
V ₅	1/2 5670	C	Cathode Follower
V ₆	1/2 6J6	C	Audio Amplifier
V ₇	6C4	C	Slave Blocking Oscillator
V ₉	1/2 6J6	B	Delay Multivibrator
V ₁₀ (X ₉)	1/2 6J6	B	Delay Multivibrator
V ₁₁	6C4	B	Slave Blocking Oscillator
V ₁₃ (X ₁₂)	1/2 5670	A	Free Running Blocking Oscillator
V ₁₄	1/2 6J6	D	Delay Multivibrator
V ₁₅ (X ₁₄)	1/2 6J6	D	Delay Multivibrator
V ₁₆	6C4	D	Slave Blocking Oscillator
V ₁₇	1/2 5670	D	Cathode Follower
V ₁₈	1/2 6J6	E	Delay Multivibrator
V ₁₉ (X ₁₈)	1/2 6J6	E	Delay Multivibrator
V ₂₀	6C4	E	Slave Blocking Oscillator
V ₂₁ (X ₁₇)	1/2 5670	E	Cathode Follower
V ₂₂	1/2 6J6	F	Delay Multivibrator
V ₂₃ (X ₂₂)	1/2 6J6	F	Delay Multivibrator
V ₂₄	6C4	F	Slave Blocking Oscillator
V ₂₅	1/2 5670	F	Cathode Follower

Vacuum Tube Summary

Tube	Type	Quantity	Function
V1	6X4	1	Rectifier
V2 (V1)	6X4	1	Rectifier
V3	6AV6	1	Diode Clipper
V4 (V2)	6X4	1	Inverter-Excitation
V5	6X4	1	Control Amplifier
V6	6X4	1	Control Amplifier
V7	6X4	1	Slave Oscillator
V8	6X4	1	Slave Oscillator
V9 (V3)	6X4	1	Slave Oscillator
V10	6X4	1	Slave Oscillator
V11 (V4)	6X4	1	Slave Oscillator
V12 (V5)	6X4	1	Slave Oscillator
V13	6X4	1	Slave Oscillator
V14 (V6)	6X4	1	Slave Oscillator
V15	6X4	1	Slave Oscillator
V16	6X4	1	Slave Oscillator
V17 (V7)	6X4	1	Slave Oscillator
V18	6X4	1	Slave Oscillator
V19 (V8)	6X4	1	Slave Oscillator
V20	6X4	1	Slave Oscillator
V21 (V9)	6X4	1	Slave Oscillator
V22	6X4	1	Slave Oscillator
V23 (V10)	6X4	1	Slave Oscillator
V24	6X4	1	Slave Oscillator
V25 (V11)	6X4	1	Slave Oscillator
V26	6X4	1	Slave Oscillator
V27 (V12)	6X4	1	Slave Oscillator
V28	6X4	1	Slave Oscillator
V29 (V13)	6X4	1	Slave Oscillator
V30	6X4	1	Slave Oscillator
V31 (V14)	6X4	1	Slave Oscillator
V32	6X4	1	Slave Oscillator
V33 (V15)	6X4	1	Slave Oscillator
V34	6X4	1	Slave Oscillator
V35 (V16)	6X4	1	Slave Oscillator
V36	6X4	1	Slave Oscillator
V37 (V17)	6X4	1	Slave Oscillator
V38	6X4	1	Slave Oscillator
V39 (V18)	6X4	1	Slave Oscillator
V40	6X4	1	Slave Oscillator
V41 (V19)	6X4	1	Slave Oscillator
V42	6X4	1	Slave Oscillator
V43 (V20)	6X4	1	Slave Oscillator
V44	6X4	1	Slave Oscillator
V45 (V21)	6X4	1	Slave Oscillator
V46	6X4	1	Slave Oscillator
V47 (V22)	6X4	1	Slave Oscillator
V48	6X4	1	Slave Oscillator
V49 (V23)	6X4	1	Slave Oscillator
V50	6X4	1	Slave Oscillator
V51 (V24)	6X4	1	Slave Oscillator
V52	6X4	1	Slave Oscillator
V53 (V25)	6X4	1	Slave Oscillator
V54	6X4	1	Slave Oscillator
V55 (V26)	6X4	1	Slave Oscillator
V56	6X4	1	Slave Oscillator
V57 (V27)	6X4	1	Slave Oscillator
V58	6X4	1	Slave Oscillator
V59 (V28)	6X4	1	Slave Oscillator
V60	6X4	1	Slave Oscillator
V61 (V29)	6X4	1	Slave Oscillator
V62	6X4	1	Slave Oscillator
V63 (V30)	6X4	1	Slave Oscillator
V64	6X4	1	Slave Oscillator
V65 (V31)	6X4	1	Slave Oscillator
V66	6X4	1	Slave Oscillator
V67 (V32)	6X4	1	Slave Oscillator
V68	6X4	1	Slave Oscillator
V69 (V33)	6X4	1	Slave Oscillator
V70	6X4	1	Slave Oscillator
V71 (V34)	6X4	1	Slave Oscillator
V72	6X4	1	Slave Oscillator
V73 (V35)	6X4	1	Slave Oscillator
V74	6X4	1	Slave Oscillator
V75 (V36)	6X4	1	Slave Oscillator
V76	6X4	1	Slave Oscillator
V77 (V37)	6X4	1	Slave Oscillator
V78	6X4	1	Slave Oscillator
V79 (V38)	6X4	1	Slave Oscillator
V80	6X4	1	Slave Oscillator
V81 (V39)	6X4	1	Slave Oscillator
V82	6X4	1	Slave Oscillator
V83 (V40)	6X4	1	Slave Oscillator
V84	6X4	1	Slave Oscillator
V85 (V41)	6X4	1	Slave Oscillator
V86	6X4	1	Slave Oscillator
V87 (V42)	6X4	1	Slave Oscillator
V88	6X4	1	Slave Oscillator
V89 (V43)	6X4	1	Slave Oscillator
V90	6X4	1	Slave Oscillator
V91 (V44)	6X4	1	Slave Oscillator
V92	6X4	1	Slave Oscillator
V93 (V45)	6X4	1	Slave Oscillator
V94	6X4	1	Slave Oscillator
V95 (V46)	6X4	1	Slave Oscillator
V96	6X4	1	Slave Oscillator
V97 (V47)	6X4	1	Slave Oscillator
V98	6X4	1	Slave Oscillator
V99 (V48)	6X4	1	Slave Oscillator
V100	6X4	1	Slave Oscillator

<u>Tube</u>	<u>Type</u>	<u>Channel</u>	<u>Function</u>
V ₂₆	16J6	G	Delay Multivibrator
V ₂₇ (X ₂₆)	16J6	G	Delay Multivibrator
V ₂₈	6C4	G	Slave Blocking Oscillator
V ₂₉ (X ₂₅)	15670	G	Cathode Follower
V ₃₀	16J6	H	Delay Multivibrator
V ₃₁ (X ₃₀)	16J6	H	Delay Multivibrator
V ₃₂	6C4	H	Slave Blocking Oscillator
V ₃₃	15670	H	Cathode Follower
V ₃₄	0A2	J	Voltage Regulator
V ₃₅	6X4	J	Full Wave Rectifier
V ₃₆	6X4	J	Full Wave Rectifier
V ₃₇	6X4	J	Full Wave Rectifier
V ₃₈	6AS7G	J	Current Control
V ₃₉	6AK5	J	Bias Control
V ₄₀	15670	G	Cathode Follower
V ₄₁	6AN5	K	Inverter-Amplifier
V ₄₃	15670	D	Cathode Follower
V ₄₄ (X ₅)	15670	E	Cathode Follower
V ₄₅ (X ₄₃)	15670	F	Cathode Follower
V ₄₆ (X ₄₀)	15670	H	Cathode Follower
V ₄₇	6AN5	K	Inverter-Amplifier
V ₄₈	15670	K	Cathode Follower
V ₄₉ (X ₄₈)	15670	K	Cathode Follower

<u>Tube</u>	<u>Type</u>	<u>Channel</u>	<u>Function</u>
V26	6X15	G	Delay Multiplier
V27 (X26)	6X15	G	Delay Multiplier
V28	6C4	G	Slave Blocking Oscillator
V29 (X25)	6E67	G	Cathode Follower
V30	6X15	H	Delay Multiplier
V31 (X30)	6X15	H	Delay Multiplier
V32	6C4	H	Slave Blocking Oscillator
V33	6E67	H	Cathode Follower
V34	6A5	I	Voltage Regulator
V35	6X1	I	Full Wave Rectifier
V36	6X1	I	Full Wave Rectifier
V37	6X1	I	Full Wave Rectifier
V38	6E67	I	Current Control
V39	6A5	I	Bias Control
V40	6E67	G	Cathode Follower
V41	6A5	H	Inverter-Amplifier
V42	6E67	B	Cathode Follower
V43 (X2)	6E67	B	Cathode Follower
V44 (X13)	6E67	T	Cathode Follower
V45 (X10)	6E67	H	Cathode Follower
V46	6A5	I	Inverter-Amplifier
V47	6E67	H	Cathode Follower
V48 (X1)	6E67	H	Cathode Follower

All resistors $\frac{1}{2}$ watt unless otherwise noted.

<u>R</u>	<u>Channel</u>	<u>Size</u>	<u>R</u>	<u>Channel</u>	<u>Size</u>
2	C	500K 2W pot.	33	B	15K
3	C	100K 2W pot.	34	B	220 ohm
4	C	1K 2W pot.	35	B	10K 1W
5	A	5M 2W pot.	36	B	220K
7	D	500K 2W pot.	37	B	270K
8	J	100K 2W pot.	38	C	9.1K
9	E	500K 2W pot.	39	C	56K
10	F	500K 2W pot.	40	C	470K
11	G	500K 2W pot.	41	C	10K 1W
12	H	500K 2W pot.	42	C	560K
13	J	82K 1W	43	C	10K 1W
14	J	68K	44	C	47K
15	J	300K	45	C	6.8K
18	J	11.2K 5W	46	C	13.2K 1W
20	J	500 ohm 20W (tapped)	47	C	100 ohm
24	A	2.7K	48	C	5.1K
25	A	100 ohm	50	C	91 ohm
26	A	5.1K	51	C	13.8K 1W
27	B	10K 1W	52	C	100K
28	B	470K	53	C	6.8K
29	B	50K	54	C	100K
30	B	500K 2W pot.	55	C	910 ohm
31	B	560K	56	C	5.6K 1W
32	B	10K 1W	57	C	82K 1W

ALL notations in left margin are indicated.

Size	Channel	H	Size	Channel	H
12K	B	33	200K SW bot.	C	3
120 ohm	B	34	100K SW bot.	C	3
10K 1W	B	35	1K SW bot.	C	4
220K	B	36	2M SW bot.	A	2
270K	B	37	200K SW bot.	B	3
3.1K	C	38	100K SW bot.	A	3
20K	C	39	200K SW bot.	B	3
110K	B	40	200K SW bot.	B	3
10K 1W	C	41	200K SW bot.	B	3
220K	C	42	100K SW bot.	H	11
10K 1W	C	43	10K 1W	A	13
2.1K	C	44	10K	A	14
0.6K	D	45	200K	A	15
15.2K 1W	E	46	11.2K 2W	A	16
100 ohm	C	47	200 ohm 10W (capped)	A	20
2.1K	B	48	3.1K	A	21
10 ohm	C	49	100 ohm	A	22
13.2K 1W	B	50	2.1K	A	23
100K	C	51	10K 1W	B	24
0.6K	C	52	200K	B	25
100K	C	53	10K	B	26
210 ohm	C	54	100 ohm	A	27
2.1K 1W	A	55	10K	A	28
10K 1W	A	56	10K	A	29

<u>R</u>	<u>Channel</u>	<u>Size</u>	<u>R</u>	<u>Channel</u>	<u>Size</u>
58	K	270K	83	D	10K 1W
59	K	680K	84	D	100 ohm
60	K	1.5K 1W	85	D	220K
61	K	68K	86	D	270K
62	K	220K	87	D	820K
63	K	3.3M	88	D	6.8K
64	K	1M	89	E	820K
65	K	3.3M	90	E	6.8K
66	K	8.9K 2W	91	E	56K
67	K	41K	92	E	470K
68	K	4K	93	E	10K 1W
69	K	2.5K 1W	94	E	560K
70	K	68K	95	E	10K 1W
71	K	56K	96	E	15K
72	K	47K	97	E	10K 1W
73	K	3.3K	98	E	100 ohm
74	K	100K	99	E	220K
75	D	820K	100	E	270K
76	D	6.8K	101	E	820K
77	D	56K	102	E	6.8K
78	D	470K	103	F	820K
79	D	10K 1W	104	F	6.8K
80	D	560K	105	F	56K
81	D	10K 1W	106	F	470K
82	D	15K	107	F	10K 1W

Size	Channel	Size	Channel
10K 1M	D	210K	K
100 0.1M	D	660K	K
250K	D	1.2M 1M	K
210K	D	68K	K
250K	D	250K	K
0.8K	D	2.3M	K
650K	K	1M	K
2.5K	D	3.3M	K
25K	D	0.3K 2K	K
110K	D	11K	K
10K 1M	D	11K	K
250K	K	5.7M 1M	K
10K 1M	D	65K	K
12K	D	20K	K
10K 1M	D	11K	K
100 0.1M	D	3.3M	K
250K	D	100K	K
250K	D	250K	D
0.8K	D	0.4K	D
250K	D	25K	D
250K	D	1.50K	D
0.4K	D	10K 1M	D
25K	D	250K	D
150K	D	150K	D
10K 1M	D	10K 1M	D

<u>R</u>	<u>Channel</u>	<u>Size</u>
108	F	560K
109	F	10K 1W
110	F	15K
111	F	10K 1W
112	F	100 ohm
113	F	220K
114	F	270K
115	F	820K
116	F	6.8K
117	G	820K
118	G	6.8K
119	G	56K
120	G	470K
121	G	10K 1W
122	G	560K
123	G	10K 1W
124	G	15K
125	G	10K 1W
126	G	100 ohm
127	G	220K
128	G	270K
129	G	820K
130	G	6.8K
131	H	820K

<u>R</u>	<u>Channel</u>	<u>Size</u>
132	H	6.8K
133	H	56K
134	H	470K
135	H	10K 1W
136	H	560K
137	H	10K 1W
138	H	15K
139	H	10K 1W
140	H	100 ohm
141	H	220K
142	H	270K
143	H	820K
144	H	6.8K
145	H	2.2K
146	C	10K

<u>Site</u>	<u>County</u>	<u>W</u>	<u>Site</u>	<u>County</u>	<u>W</u>
0.8K	H	135	1000	H	101
2K	H	133	1001	H	102
40K	H	134	1002	H	103
100 1W	H	132	1003	H	104
200	H	131	1004	H	105
100 1W	H	130	1005	H	106
100 1W	H	129	1006	H	107
100 1W	H	128	1007	H	108
100 1W	H	127	1008	H	109
100 1W	H	126	1009	H	110
100 1W	H	125	1010	H	111
100 1W	H	124	1011	H	112
100 1W	H	123	1012	H	113
100 1W	H	122	1013	H	114
100 1W	H	121	1014	H	115
100 1W	H	120	1015	H	116
100 1W	H	119	1016	H	117
100 1W	H	118	1017	H	118
100 1W	H	117	1018	H	119
100 1W	H	116	1019	H	120
100 1W	H	115	1020	H	121
100 1W	H	114	1021	H	122
100 1W	H	113	1022	H	123
100 1W	H	112	1023	H	124
100 1W	H	111	1024	H	125
100 1W	H	110	1025	H	126
100 1W	H	109	1026	H	127
100 1W	H	108	1027	H	128
100 1W	H	107	1028	H	129
100 1W	H	106	1029	H	130
100 1W	H	105	1030	H	131
100 1W	H	104	1031	H	132
100 1W	H	103	1032	H	133
100 1W	H	102	1033	H	134
100 1W	H	101	1034	H	135
100 1W	H	100	1035	H	136
100 1W	H	99	1036	H	137
100 1W	H	98	1037	H	138
100 1W	H	97	1038	H	139
100 1W	H	96	1039	H	140
100 1W	H	95	1040	H	141
100 1W	H	94	1041	H	142
100 1W	H	93	1042	H	143
100 1W	H	92	1043	H	144
100 1W	H	91	1044	H	145
100 1W	H	90	1045	H	146
100 1W	H	89	1046	H	147
100 1W	H	88	1047	H	148
100 1W	H	87	1048	H	149
100 1W	H	86	1049	H	150
100 1W	H	85	1050	H	151
100 1W	H	84	1051	H	152
100 1W	H	83	1052	H	153
100 1W	H	82	1053	H	154
100 1W	H	81	1054	H	155
100 1W	H	80	1055	H	156
100 1W	H	79	1056	H	157
100 1W	H	78	1057	H	158
100 1W	H	77	1058	H	159
100 1W	H	76	1059	H	160
100 1W	H	75	1060	H	161
100 1W	H	74	1061	H	162
100 1W	H	73	1062	H	163
100 1W	H	72	1063	H	164
100 1W	H	71	1064	H	165
100 1W	H	70	1065	H	166
100 1W	H	69	1066	H	167
100 1W	H	68	1067	H	168
100 1W	H	67	1068	H	169
100 1W	H	66	1069	H	170
100 1W	H	65	1070	H	171
100 1W	H	64	1071	H	172
100 1W	H	63	1072	H	173
100 1W	H	62	1073	H	174
100 1W	H	61	1074	H	175
100 1W	H	60	1075	H	176
100 1W	H	59	1076	H	177
100 1W	H	58	1077	H	178
100 1W	H	57	1078	H	179
100 1W	H	56	1079	H	180
100 1W	H	55	1080	H	181
100 1W	H	54	1081	H	182
100 1W	H	53	1082	H	183
100 1W	H	52	1083	H	184
100 1W	H	51	1084	H	185
100 1W	H	50	1085	H	186
100 1W	H	49	1086	H	187
100 1W	H	48	1087	H	188
100 1W	H	47	1088	H	189
100 1W	H	46	1089	H	190
100 1W	H	45	1090	H	191
100 1W	H	44	1091	H	192
100 1W	H	43	1092	H	193
100 1W	H	42	1093	H	194
100 1W	H	41	1094	H	195
100 1W	H	40	1095	H	196
100 1W	H	39	1096	H	197
100 1W	H	38	1097	H	198
100 1W	H	37	1098	H	199
100 1W	H	36	1099	H	200
100 1W	H	35	1100	H	201
100 1W	H	34	1101	H	202
100 1W	H	33	1102	H	203
100 1W	H	32	1103	H	204
100 1W	H	31	1104	H	205
100 1W	H	30	1105	H	206
100 1W	H	29	1106	H	207
100 1W	H	28	1107	H	208
100 1W	H	27	1108	H	209
100 1W	H	26	1109	H	210
100 1W	H	25	1110	H	211
100 1W	H	24	1111	H	212
100 1W	H	23	1112	H	213
100 1W	H	22	1113	H	214
100 1W	H	21	1114	H	215
100 1W	H	20	1115	H	216
100 1W	H	19	1116	H	217
100 1W	H	18	1117	H	218
100 1W	H	17	1118	H	219
100 1W	H	16	1119	H	220
100 1W	H	15	1120	H	221
100 1W	H	14	1121	H	222
100 1W	H	13	1122	H	223
100 1W	H	12	1123	H	224
100 1W	H	11	1124	H	225
100 1W	H	10	1125	H	226
100 1W	H	9	1126	H	227
100 1W	H	8	1127	H	228
100 1W	H	7	1128	H	229
100 1W	H	6	1129	H	230
100 1W	H	5	1130	H	231
100 1W	H	4	1131	H	232
100 1W	H	3	1132	H	233
100 1W	H	2	1133	H	234
100 1W	H	1	1134	H	235
100 1W	H	0	1135	H	236

All capacitors 200 WV unless otherwise noted.

<u>C</u>	<u>Channel</u>	<u>Size</u>	<u>C</u>	<u>Channel</u>	<u>Size</u>
1	J	40 mf 450 WV	27	C	.05
2	J	40 mf 450 WV	28	C	.05
5	A	100	29	C	400 300 WV
6	B	.05 300 WV	30	C	.25
7	B	100 300 WV	32	K	.001
8	B	100	33	K	.1 300 WV
9	B	32	34	K	.01 300 WV
10	B	62	35	K	.01
11	B	.002	36	K	.001 300 WV
12	B	.01 300 WV	37	K	.01 300 WV
13	B	.01	38	K	.01
14	B	.05	39	K	.01
15	C	100	40	K	400 300 WV
16	C	100 300 WV	41	K	.01 300 WV
17	C	5	42	K	.01
18	C	.002	43	K	.05
19	C	.1 300 WV	44	K	.01 300 WV
20	C	.01	45	D	100 300 WV
21	C	.005	46	D	100
22	C	100 300 WV	47	D	10 300 WV
23	C	200	48	D	62
24	C	.001 300 WV	49	D	.002
25	C	.068	50	D	.01 300 WV
26	C	.01	51	D	.01

All capacitors 500 W unless otherwise noted.

C	Channel	Size	C	Channel	Size
1	1	100 m 150 W	27	C	.02
2	1	100 m 150 W	28	C	.02
3	A	100	29	C	100 300 W
4	B	.02 300 W	30	C	.25
5	B	100 300 W	31	K	.001
6	B	100	32	K	.1 300 W
7	B	35	33	K	.01 300 W
8	B	.02	34	K	.01
9	B	.005	35	K	.001 300 W
10	B	.01 300 W	36	K	.01 300 W
11	B	.01	37	K	.01
12	B	.02	38	K	.01
13	C	100	39	K	100 300 W
14	C	100 300 W	40	K	.01 300 W
15	C	2	41	K	.01
16	C	.005	42	K	.02
17	C	.1 300 W	43	K	.01 300 W
18	C	.01	44	B	100 300 W
19	C	.002	45	B	100
20	C	100 300 W	46	B	.02
21	C	.01 300 W	47	B	.005
22	C	.01	48	B	.01 300 W
23	C	.01	49	B	.01
24	C	.01	50	B	.01
25	C	.01	51	B	.01
26	C	.01	52	B	.01
27	C	.01	53	B	.01
28	C	.01	54	B	.01
29	C	.01	55	B	.01
30	C	.01	56	B	.01
31	C	.01	57	B	.01
32	C	.01	58	B	.01
33	C	.01	59	B	.01
34	C	.01	60	B	.01
35	C	.01	61	B	.01
36	C	.01	62	B	.01
37	C	.01	63	B	.01
38	C	.01	64	B	.01
39	C	.01	65	B	.01
40	C	.01	66	B	.01
41	C	.01	67	B	.01
42	C	.01	68	B	.01
43	C	.01	69	B	.01
44	C	.01	70	B	.01
45	C	.01	71	B	.01
46	C	.01	72	B	.01
47	C	.01	73	B	.01
48	C	.01	74	B	.01
49	C	.01	75	B	.01
50	C	.01	76	B	.01
51	C	.01	77	B	.01
52	C	.01	78	B	.01
53	C	.01	79	B	.01
54	C	.01	80	B	.01
55	C	.01	81	B	.01
56	C	.01	82	B	.01
57	C	.01	83	B	.01
58	C	.01	84	B	.01
59	C	.01	85	B	.01
60	C	.01	86	B	.01
61	C	.01	87	B	.01
62	C	.01	88	B	.01
63	C	.01	89	B	.01
64	C	.01	90	B	.01
65	C	.01	91	B	.01
66	C	.01	92	B	.01
67	C	.01	93	B	.01
68	C	.01	94	B	.01
69	C	.01	95	B	.01
70	C	.01	96	B	.01
71	C	.01	97	B	.01
72	C	.01	98	B	.01
73	C	.01	99	B	.01
74	C	.01	100	B	.01

<u>C</u>	<u>Channel</u>	<u>Size</u>	<u>C</u>	<u>Channel</u>	<u>Size</u>
52	D	.05	76	G	.05
53	E	100 300 WV	77	H	100 300 WV
54	E	100	78	H	100
55	E	10 300 WV	79	H	10 300 WV
56	E	62	80	H	62
57	E	.002	81	H	.002
58	E	.01 300 WV	82	H	.01 300 WV
59	E	.01	83	H	.01
60	E	.05	84	H	.05
61	F	100 300 WV			
62	F	100			
63	F	10 300 WV			
64	F	62			
65	F	.002			
66	F	.01 300 WV			
67	F	.01			
68	F	.05			
69	G	100 300 WV			
70	G	100			
71	G	10 300 WV			
72	G	62			
73	G	.002			
74	G	.01 300 WV			
75	G	.01			

<u>C</u>	<u>Channel</u>	<u>Size</u>	<u>C</u>	<u>Channel</u>	<u>Size</u>
25	H	.05	76	G	.05
23	E	100 300 WA	77	H	100 300 WA
24	E	100	78	H	100
22	E	10 300 WA	79	H	10 300 WA
20	E	.05	80	H	.05
21	E	.005	81	H	.005
28	E	.01 300 WA	82	H	.01 300 WA
29	E	.01	83	H	.01
00	E	.05	84	H	.05
01	E	100 300 WA			
02	E	100			
03	E	10 300 WA			
04	E	.05			
05	E	.005			
06	E	.01 300 WA			
07	E	.01			
08	E	.05			
09	E	100 300 WA			
10	E	100			
11	E	10 300 WA			
12	E	.05			
13	E	.005			
14	E	.01 300 WA			
15	E	.01			

CROSS INDEX CHANNELS (D)-(H)

Channel (D)	Channel (E)	Channel (F)	Channel (G)	Channel (H)
V ₄₃	V ₄₄ (X-5)	V ₄₅ (X-43)	V ₄₀	V ₄₆ (X-40)
V ₁₄	V ₁₈	V ₂₂	V ₂₆	V ₃₀
V ₁₅ (X-14)	V ₁₉ (X-18)	V ₂₃ (X-22)	V ₂₇ (X-26)	V ₃₁ (X-30)
V ₁₆	V ₂₀	V ₂₄	V ₂₈	V ₃₂
V ₁₇	V ₂₁ (X-17)	V ₂₅	V ₂₉ (X-25)	V ₃₃
R ₇₅	R ₈₉	R ₁₀₃	R ₁₁₇	R ₁₃₁
R ₇₆	R ₉₀	R ₁₀₄	R ₁₁₈	R ₁₃₂
R ₇₇	R ₉₁	R ₁₀₅	R ₁₁₉	R ₁₃₃
R ₇₈	R ₉₂	R ₁₀₆	R ₁₂₀	R ₁₃₄
R ₈₀	R ₉₄	R ₁₀₈	R ₁₂₂	R ₁₃₆
R ₇	R ₉	R ₁₀	R ₁₁	R ₁₂
R ₈₁	R ₉₅	R ₁₀₉	R ₁₂₃	R ₁₃₇
R ₈₂	R ₉₆	R ₁₁₀	R ₁₂₄	R ₁₃₈
R ₈₃	R ₉₇	R ₁₁₁	R ₁₂₅	R ₁₃₉
R ₈₄	R ₉₈	R ₁₁₂	R ₁₂₆	R ₁₄₀
R ₈₅	R ₉₉	R ₁₁₃	R ₁₂₇	R ₁₄₁
R ₈₆	R ₁₀₀	R ₁₁₄	R ₁₂₈	R ₁₄₂
R ₈₇	R ₁₀₁	R ₁₁₅	R ₁₂₉	R ₁₄₃
R ₈₈	R ₁₀₂	R ₁₁₆	R ₁₃₀	R ₁₄₄
R ₇₉	R ₉₃	R ₁₀₇	R ₁₂₁	R ₁₃₅
C ₄₅	C ₅₃	C ₆₁	C ₆₉	C ₇₇
C ₄₆	C ₅₄	C ₆₂	C ₇₀	C ₇₈
C ₄₇	C ₅₅	C ₆₃	C ₇₁	C ₇₉

GROUP INDEX CHANNELS (D)-(H)

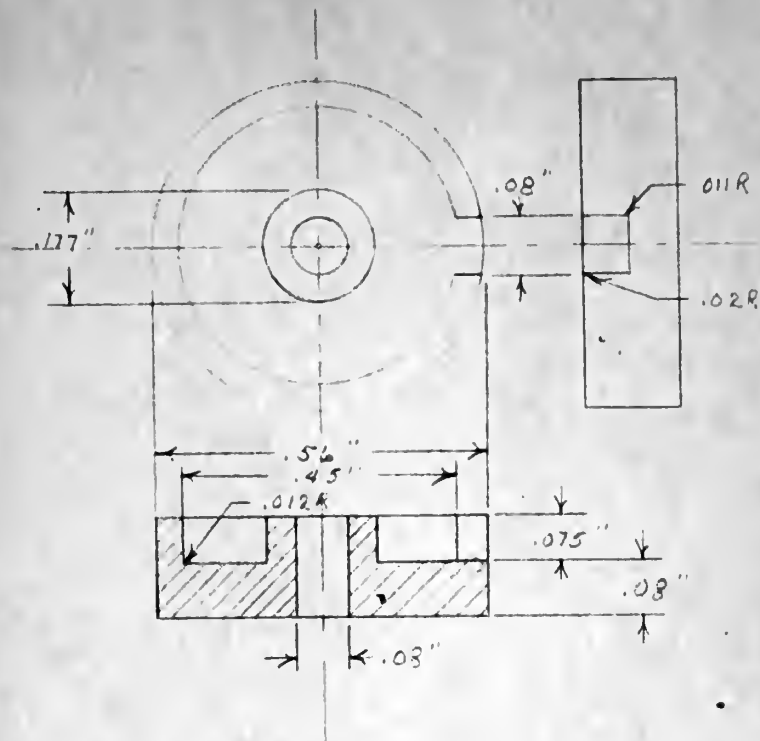
Channel (H)	Channel (G)	Channel (F)	Channel (E)	Channel (D)
V13	V13	V13 (X-13)	V13 (X-2)	V13
V14	V14	V14	V14	V14
V15 (X-15)	V15 (X-25)	V15 (X-25)	V15 (X-15)	V15
V16	V16	V16	V16	V16
V17	V17 (X-27)	V17	V17 (X-17)	V17
V18	V18	V18	V18	V18
V19	V19	V19	V19	V19
V20	V20	V20	V20	V20
V21	V21	V21	V21	V21
V22	V22	V22	V22	V22
V23	V23	V23	V23	V23
V24	V24	V24	V24	V24
V25	V25	V25	V25	V25
V26	V26	V26	V26	V26
V27	V27	V27	V27	V27
V28	V28	V28	V28	V28
V29	V29	V29	V29	V29
V30	V30	V30	V30	V30
V31	V31	V31	V31	V31
V32	V32	V32	V32	V32
V33	V33	V33	V33	V33
V34	V34	V34	V34	V34
V35	V35	V35	V35	V35
V36	V36	V36	V36	V36
V37	V37	V37	V37	V37
V38	V38	V38	V38	V38
V39	V39	V39	V39	V39
V40	V40	V40	V40	V40
V41	V41	V41	V41	V41
V42	V42	V42	V42	V42
V43	V43	V43	V43	V43
V44	V44	V44	V44	V44
V45	V45	V45	V45	V45
V46	V46	V46	V46	V46
V47	V47	V47	V47	V47
V48	V48	V48	V48	V48
V49	V49	V49	V49	V49
V50	V50	V50	V50	V50
V51	V51	V51	V51	V51
V52	V52	V52	V52	V52
V53	V53	V53	V53	V53
V54	V54	V54	V54	V54
V55	V55	V55	V55	V55
V56	V56	V56	V56	V56
V57	V57	V57	V57	V57
V58	V58	V58	V58	V58
V59	V59	V59	V59	V59
V60	V60	V60	V60	V60
V61	V61	V61	V61	V61
V62	V62	V62	V62	V62
V63	V63	V63	V63	V63
V64	V64	V64	V64	V64
V65	V65	V65	V65	V65
V66	V66	V66	V66	V66
V67	V67	V67	V67	V67
V68	V68	V68	V68	V68
V69	V69	V69	V69	V69
V70	V70	V70	V70	V70
V71	V71	V71	V71	V71
V72	V72	V72	V72	V72
V73	V73	V73	V73	V73
V74	V74	V74	V74	V74
V75	V75	V75	V75	V75
V76	V76	V76	V76	V76
V77	V77	V77	V77	V77
V78	V78	V78	V78	V78
V79	V79	V79	V79	V79
V80	V80	V80	V80	V80
V81	V81	V81	V81	V81
V82	V82	V82	V82	V82
V83	V83	V83	V83	V83
V84	V84	V84	V84	V84
V85	V85	V85	V85	V85
V86	V86	V86	V86	V86
V87	V87	V87	V87	V87
V88	V88	V88	V88	V88
V89	V89	V89	V89	V89
V90	V90	V90	V90	V90
V91	V91	V91	V91	V91
V92	V92	V92	V92	V92
V93	V93	V93	V93	V93
V94	V94	V94	V94	V94
V95	V95	V95	V95	V95
V96	V96	V96	V96	V96
V97	V97	V97	V97	V97
V98	V98	V98	V98	V98
V99	V99	V99	V99	V99
V100	V100	V100	V100	V100

Channel (D)	Channel (E)	Channel (F)	Channel (G)	Channel (H)
C ₄₈	C ₅₆	C ₆₄	C ₇₂	C ₈₀
C ₄₉	C ₅₇	C ₆₅	C ₇₃	C ₈₁
C ₅₀	C ₅₈	C ₆₆	C ₇₄	C ₈₂
C ₅₁	C ₅₉	C ₆₇	C ₇₅	C ₈₃
C ₅₂	C ₆₀	C ₆₈	C ₇₆	C ₈₄
T ₄	T ₅	T ₆	T ₇	T ₈
Y ₇	Y ₈	Y ₉	Y ₁₀	Y ₁₁
Y ₁₂	Y ₁₃	Y ₁₄	Y ₁₅	Y ₁₆
SW ₃	SW ₄	SW ₅	SW ₆	SW ₇

Cross reference TABLE for pulse generation channels (D) through (H).

Channel (A)	Channel (B)	Channel (C)	Channel (D)	Channel (E)
0.00	0.12	0.04	0.20	0.18
0.01	0.13	0.05	0.21	0.19
0.02	0.14	0.06	0.22	0.20
0.03	0.15	0.07	0.23	0.21
0.04	0.16	0.08	0.24	0.22
0.05	0.17	0.09	0.25	0.23
0.06	0.18	0.10	0.26	0.24
0.07	0.19	0.11	0.27	0.25
0.08	0.20	0.12	0.28	0.26
0.09	0.21	0.13	0.29	0.27
0.10	0.22	0.14	0.30	0.28

These values are for the following channels: (A) Channel 1, (B) Channel 2, (C) Channel 3, (D) Channel 4, (E) Channel 5.



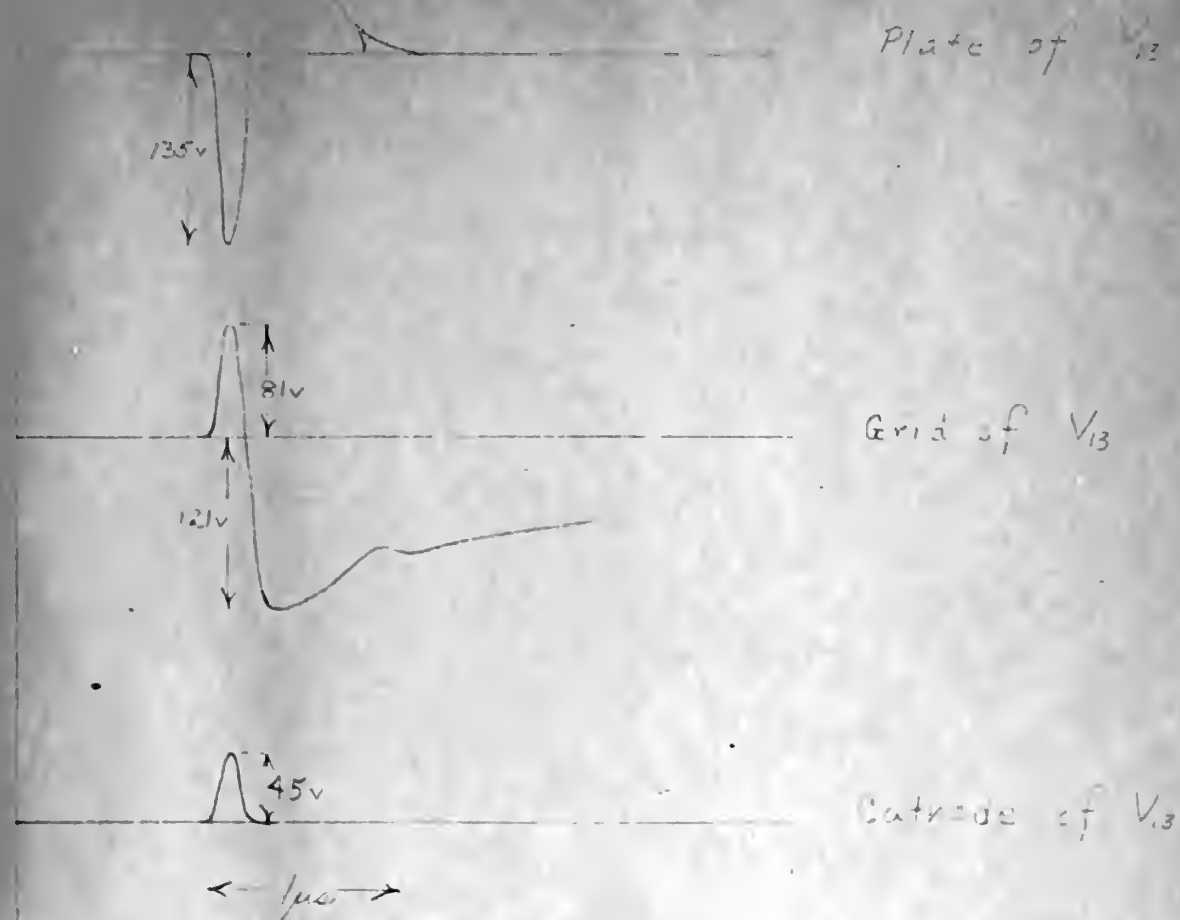
Dimensional Details of Rot Core Type 7F154, manufactured by the FERROXCUBE Corporation.

Correcto color 30ds

Pin	Yarn Class	Power Class	Purpose
A	Grey	Clear	Filament
B			
C	Grey	Clear	Filament
D	Blue	Blue	100K pot (hi side)
E			
F	Blue	Blue	100K pot. (lo side)
G			
H	Brown	Black-Grey/White	Ground
I			
J			
K	White	Green-Black/White	-42 volts
L	Olive	Yellow-Black/White	115 volts a.c.
M	Olive	Red	H.I. Xfmr (hi)
N	Clear	Blue-Black/White	150K pot. (ctr. tap)
O			
P	Pink	Red-Black/White	260 volts
Q			
R	Brown	White	Fil. Xfmr (hi)

The hi. side of the HV and Fil Xfmr's. is the side which is fused and which comes to the Fil and HV switches on the front panel.





Waveforms for Channel 1A1



Grid of V_9

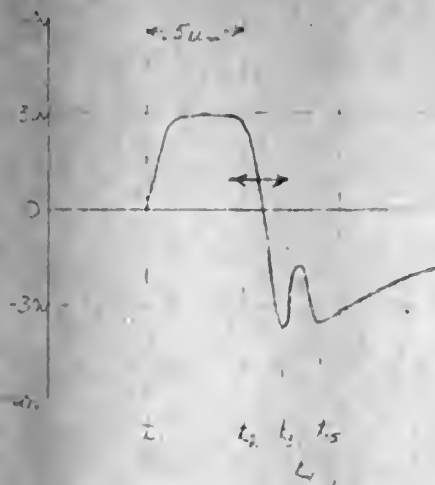


Plate of V_9

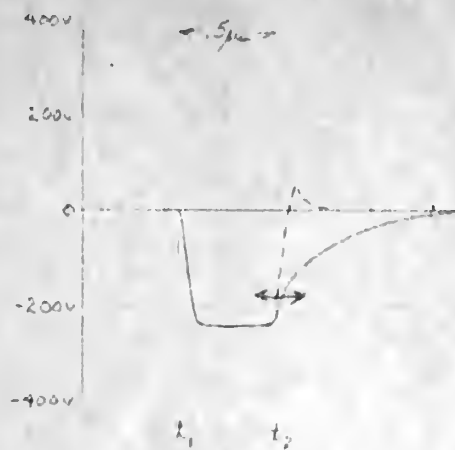


Plate of V_{10}

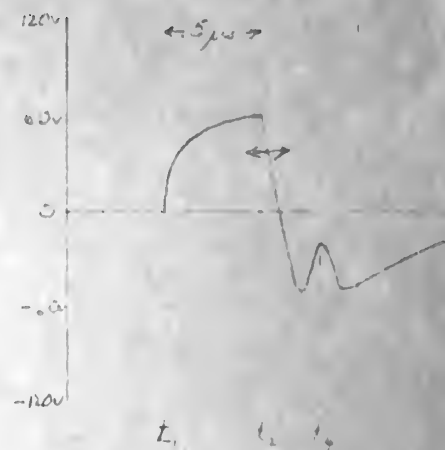
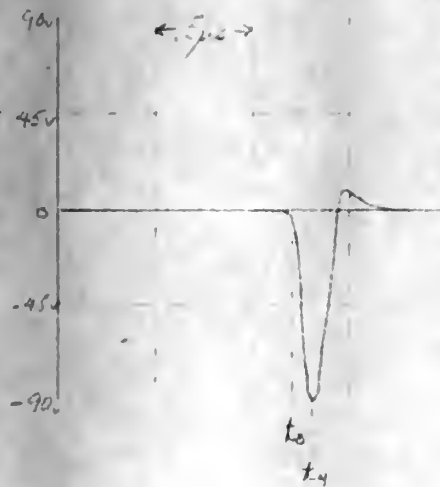
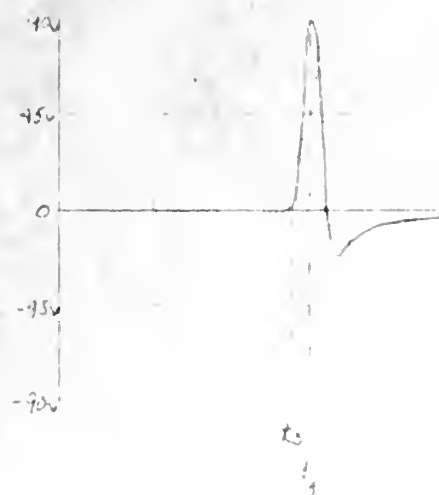


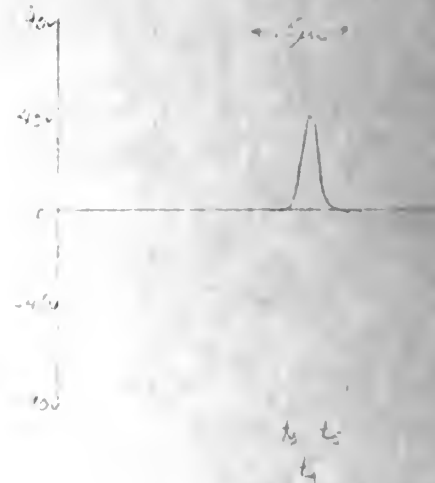
Plate of V_{11}



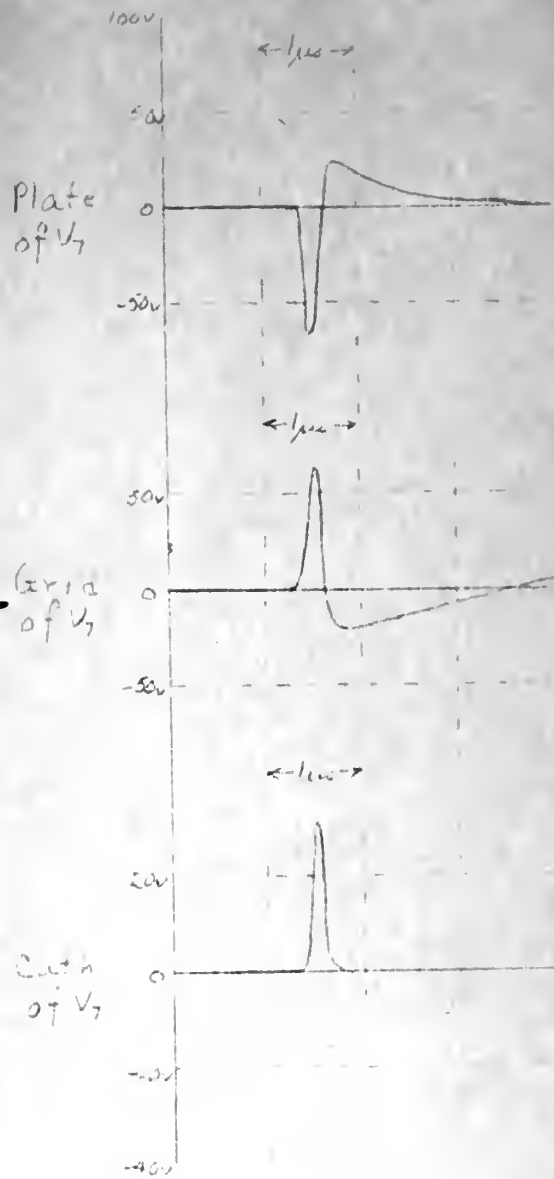
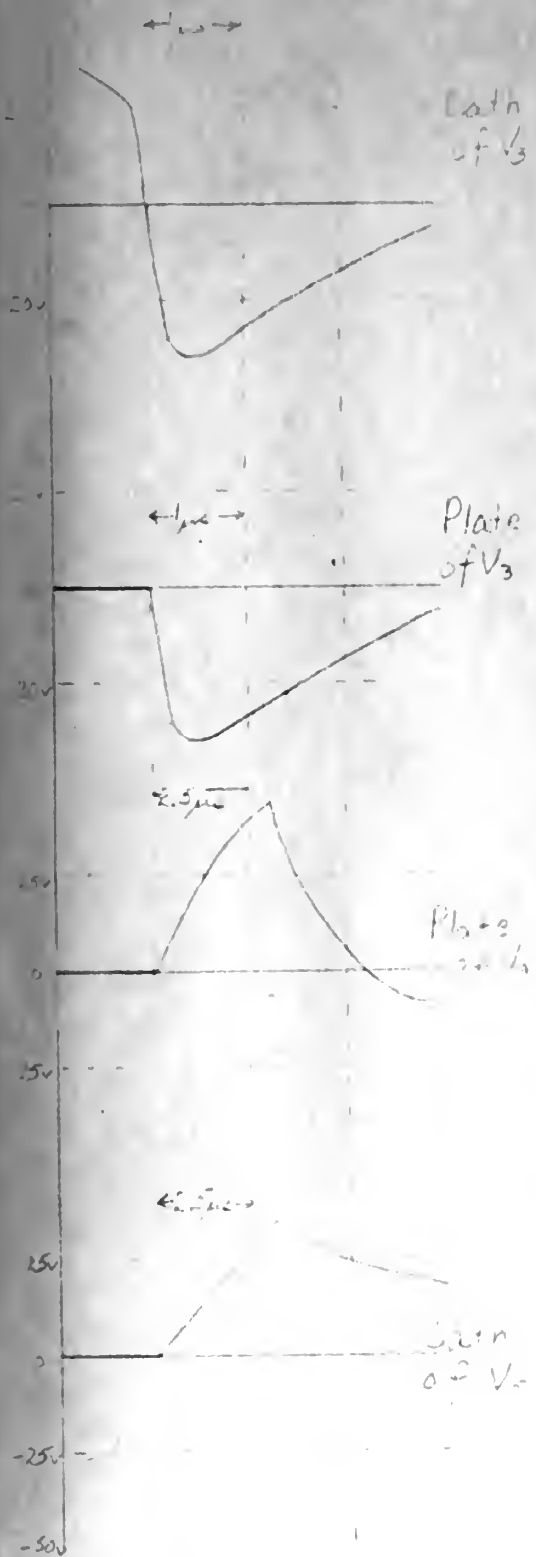
Grid of V_{12}



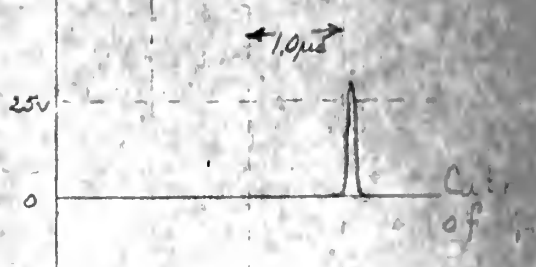
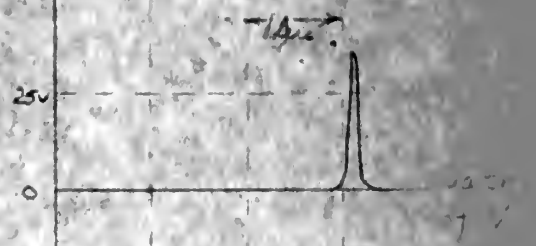
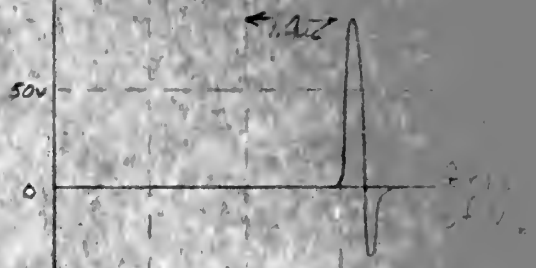
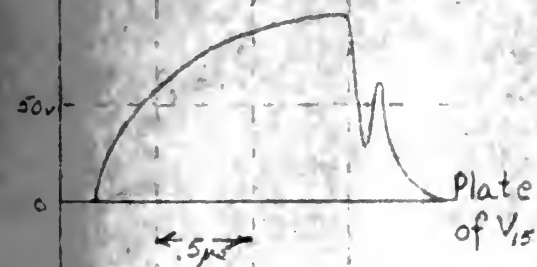
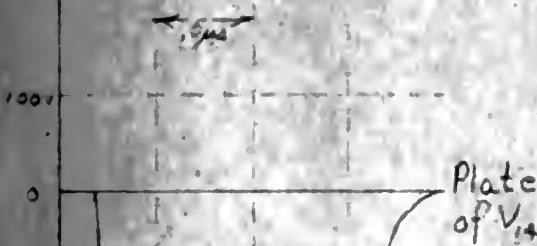
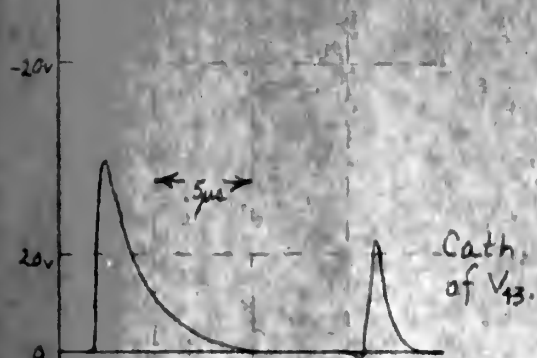
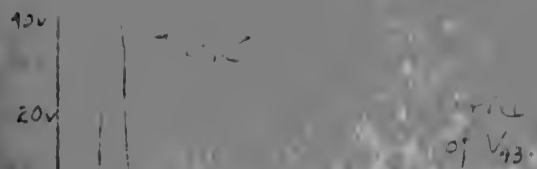
Cathode of V_{12}



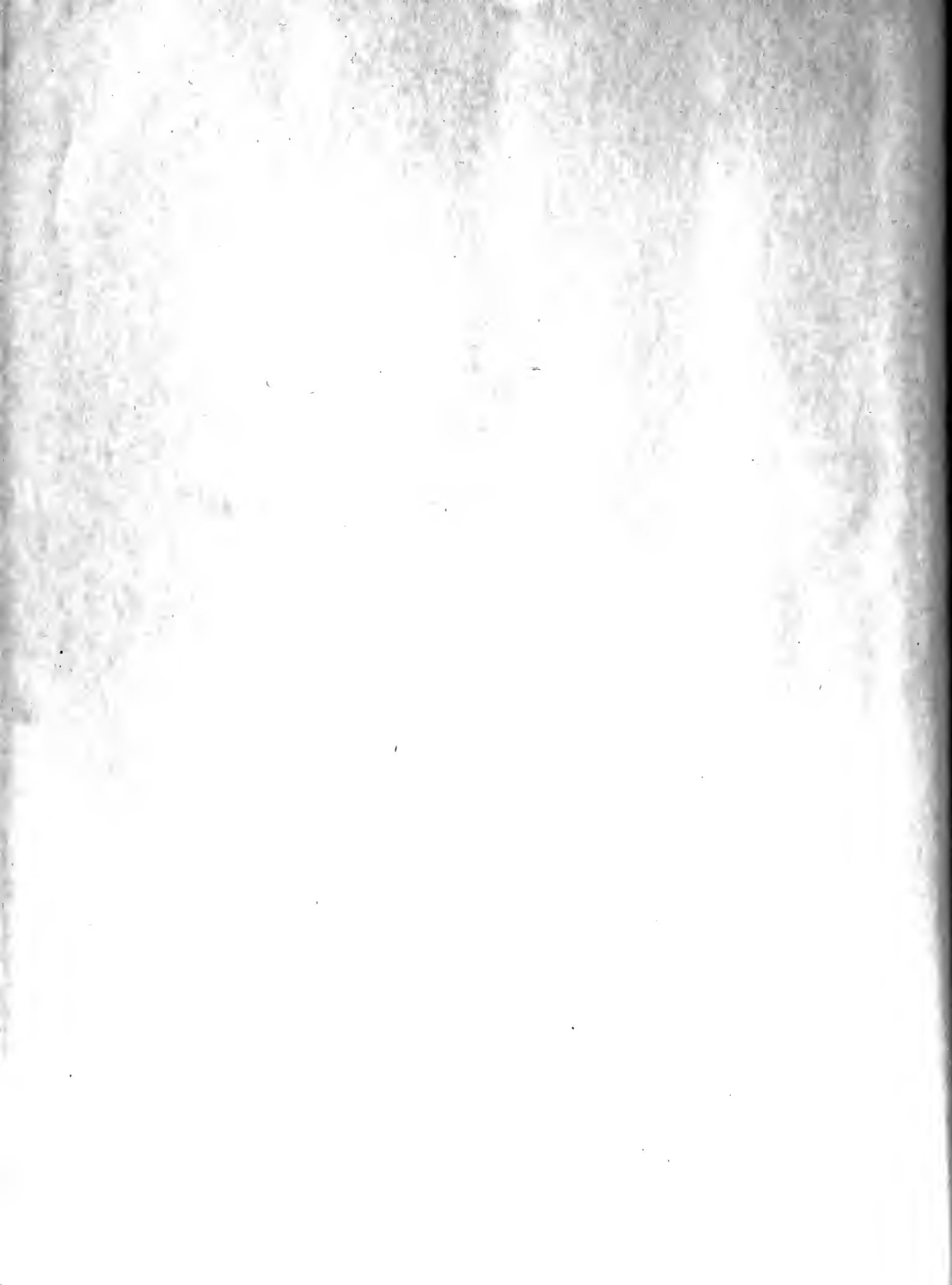
Waveforms for Channel (2)

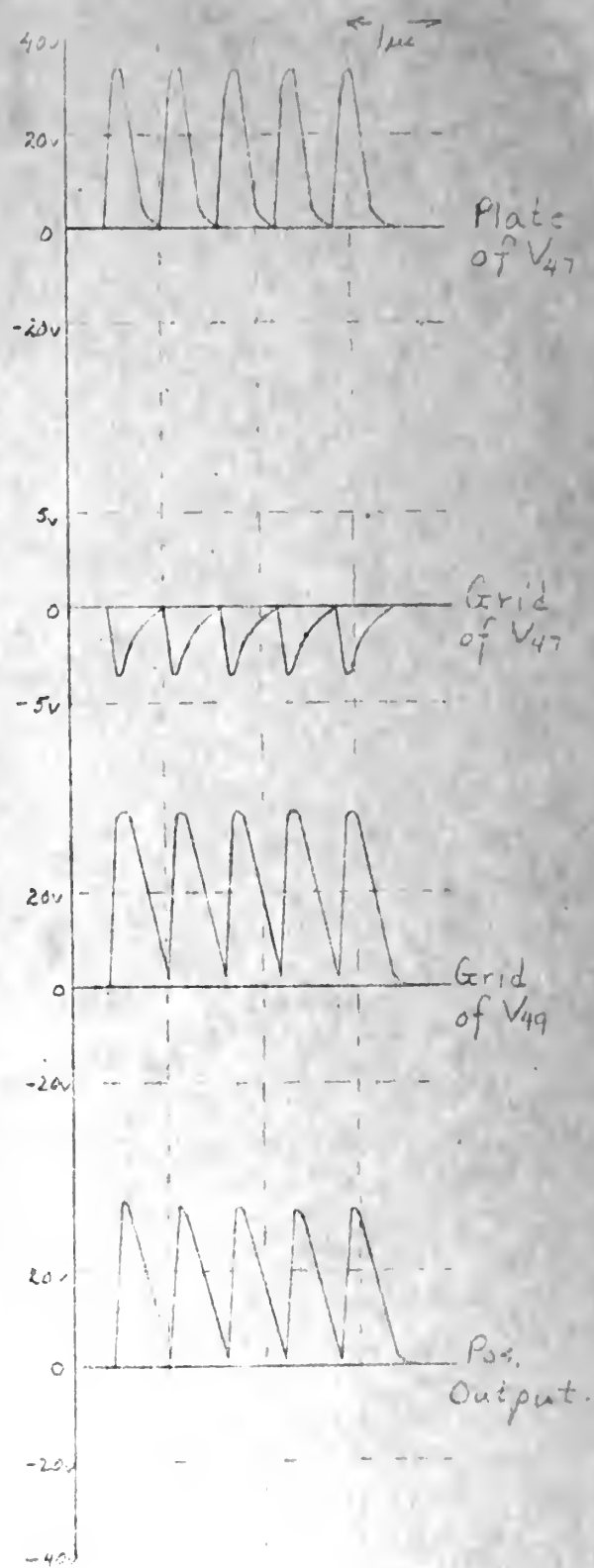
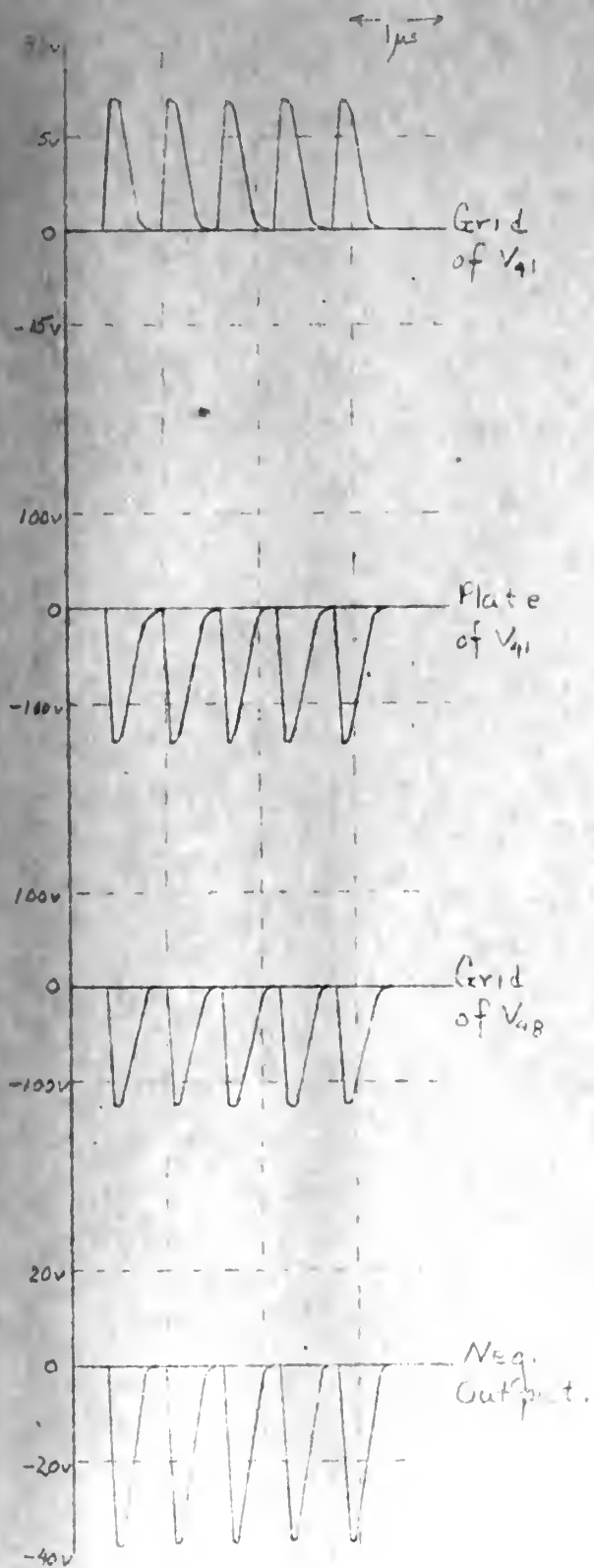


Wave a for Channel (2)

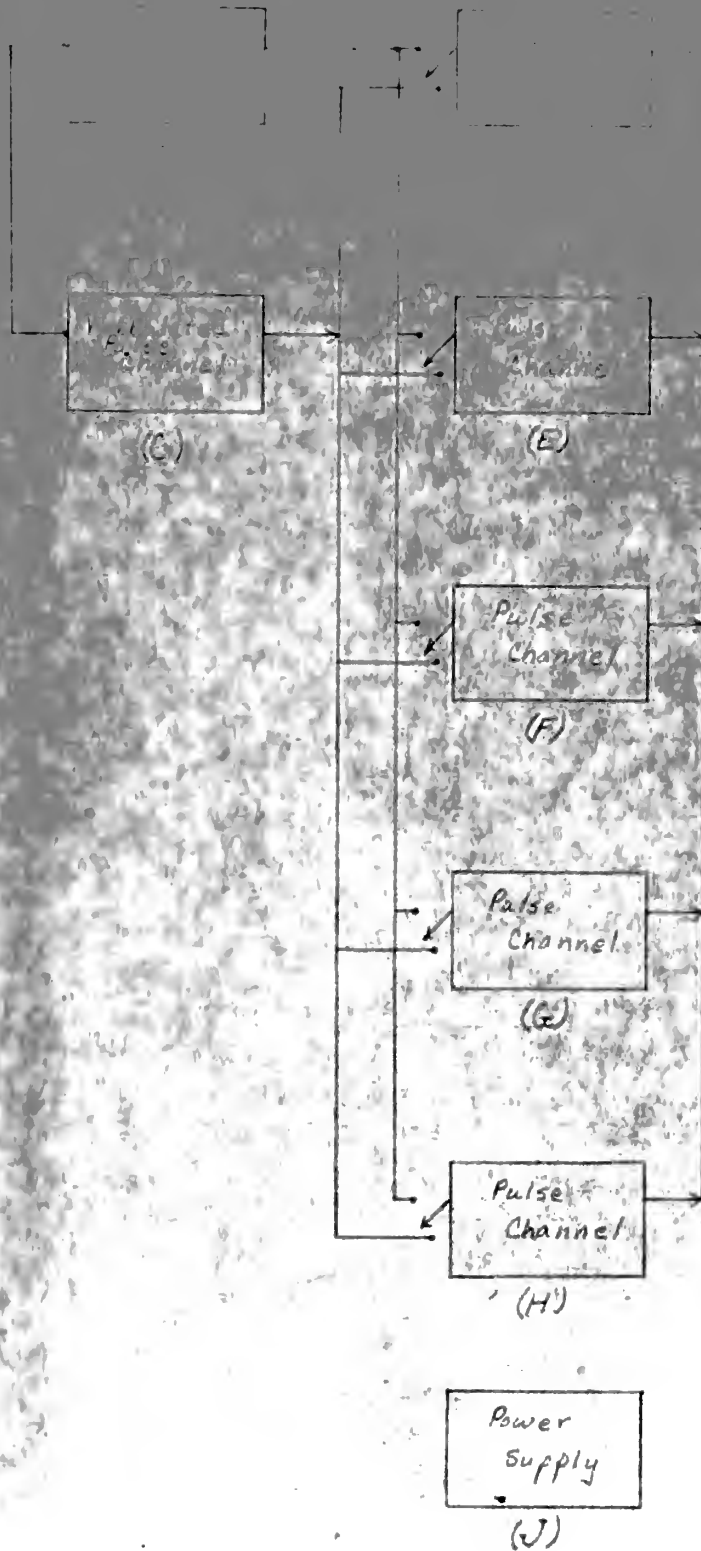


Waveform for Channel (D) [through (H)].



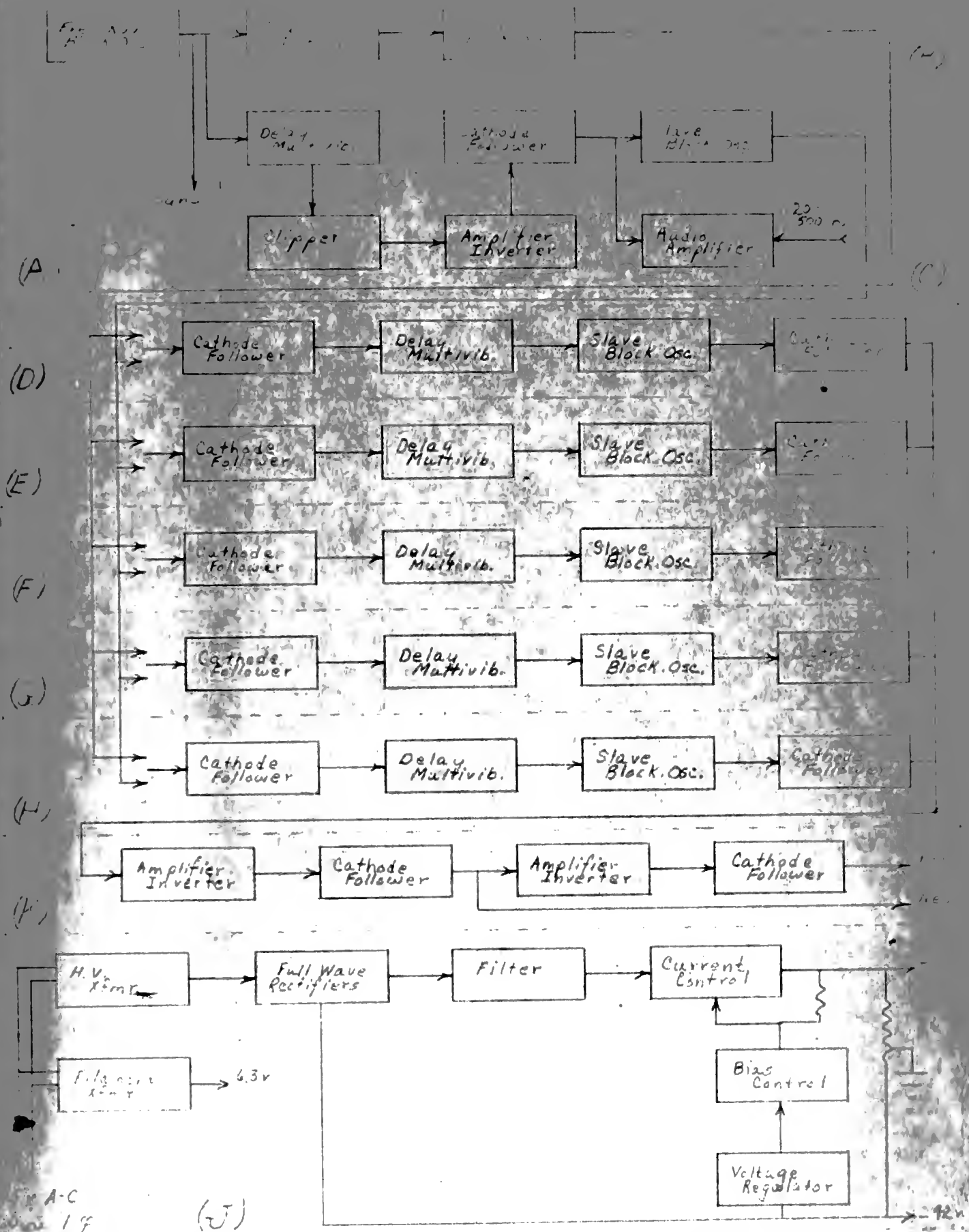


Waveforms for (K).



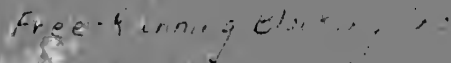
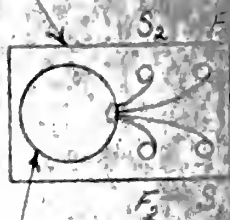
MAR 3 1952

SCALE	TITLE	MELPAR, INC.	
DRAWN <i>H. H. Hines</i>	<i>Simplified Block Diagram</i>	ALEXANDRIA, VA.	
APPROVED	MATERIAL	PROJECT NO.	EA 1
DATE <i>26 Feb 1952</i>	FINISH	<i>1153</i>	



SCALE	TITLE	MELPAR, INC.	
DRAWN	Complete Block Diagram	ALEXANDRIA, VA.	
APPROVED	MATERIAL	PROJECT NO	EA 2 MAR 3
DATE 7 Mar 1952	FINISH	# 1153	1952

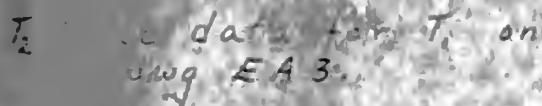
111


$$\frac{1}{8} \times \frac{3}{5} = \frac{3}{40}$$


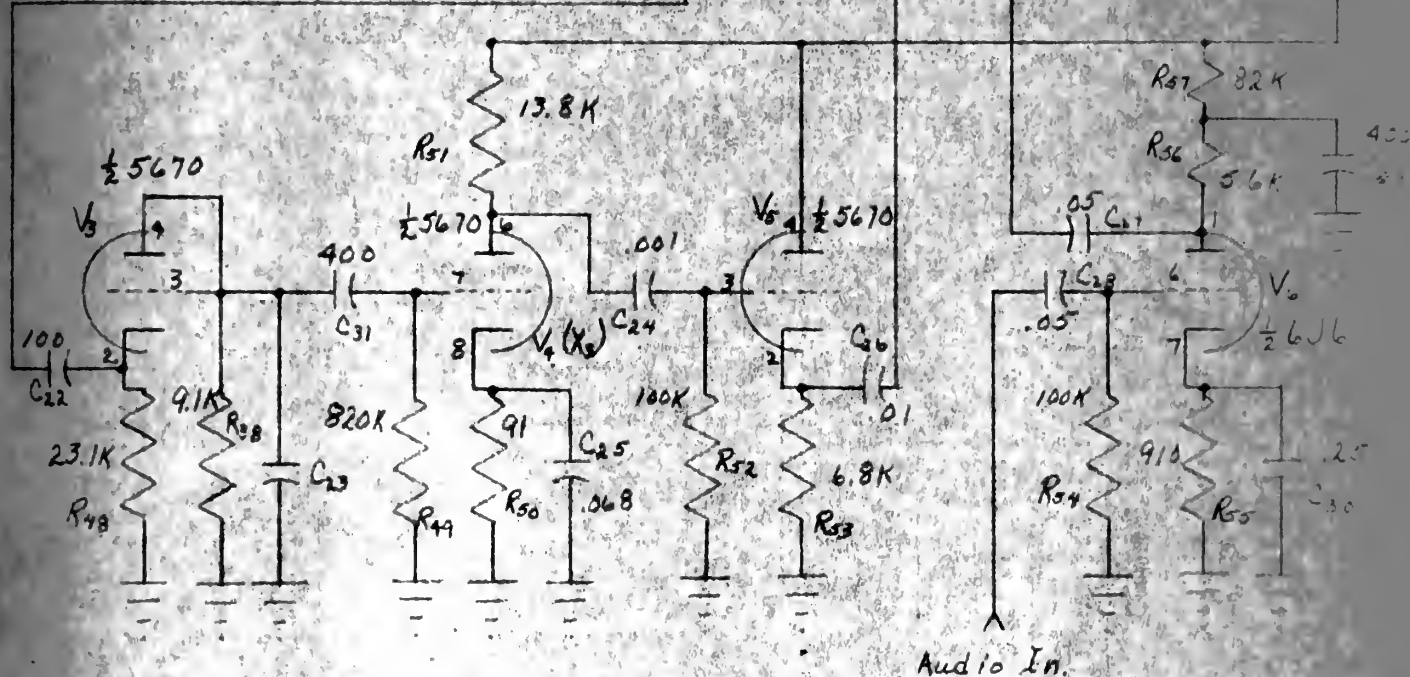
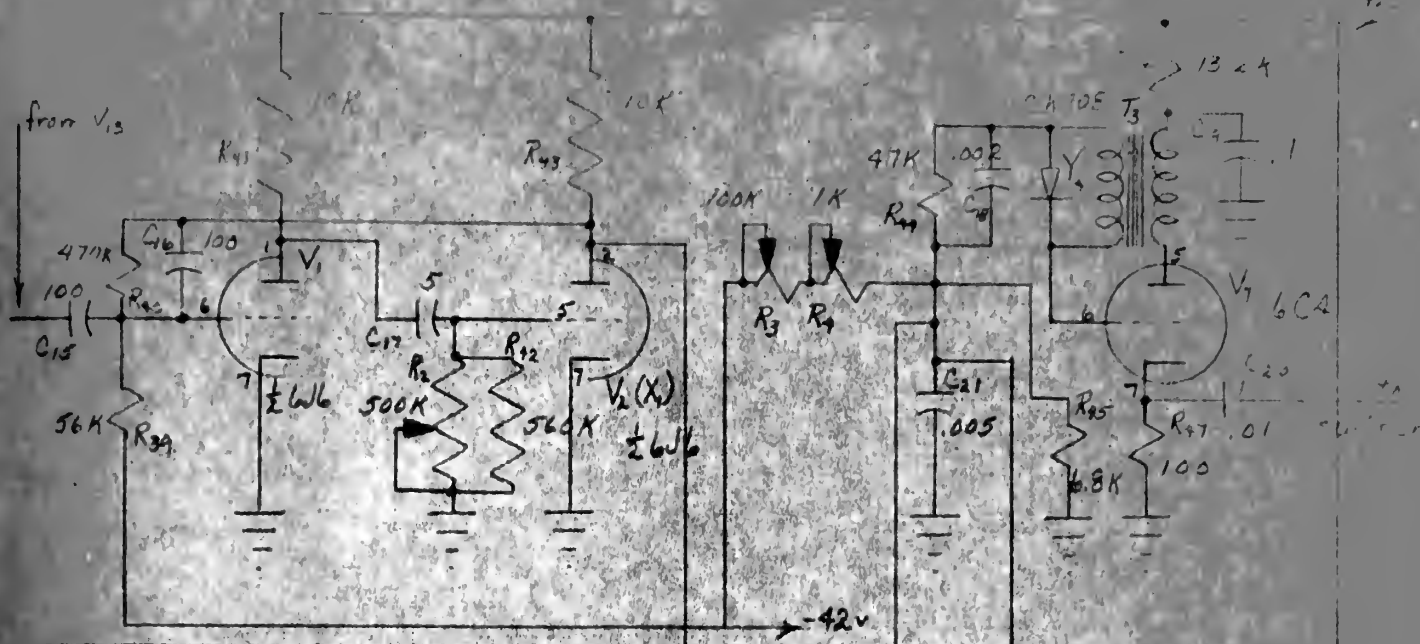
Ferroxcube
Type 7F13

MAR 7 1952

SCALE	TITLE	MELPAR, INC.	
DRAWN <i>Reinisch</i>	Channel (A) of Modulator	ALEXANDRIA, VA.	
APPROVED	MATERIAL	PROJECT NO.	EA 3
DATE 3/12/65	FINISH	# 1153	



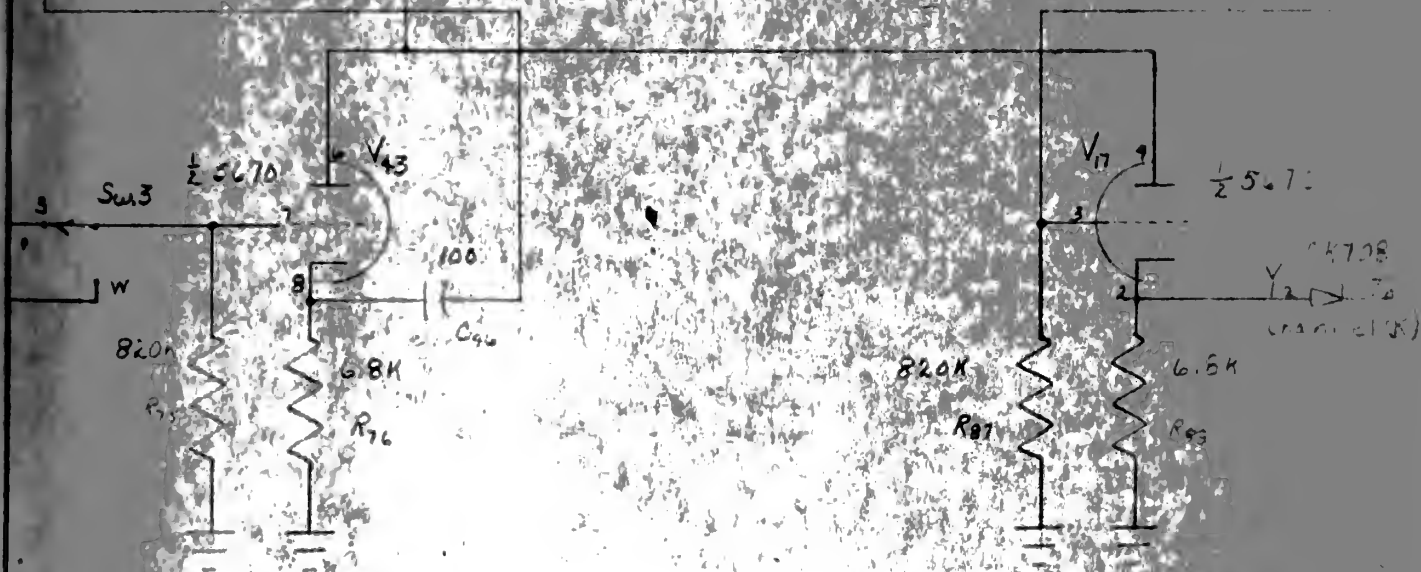
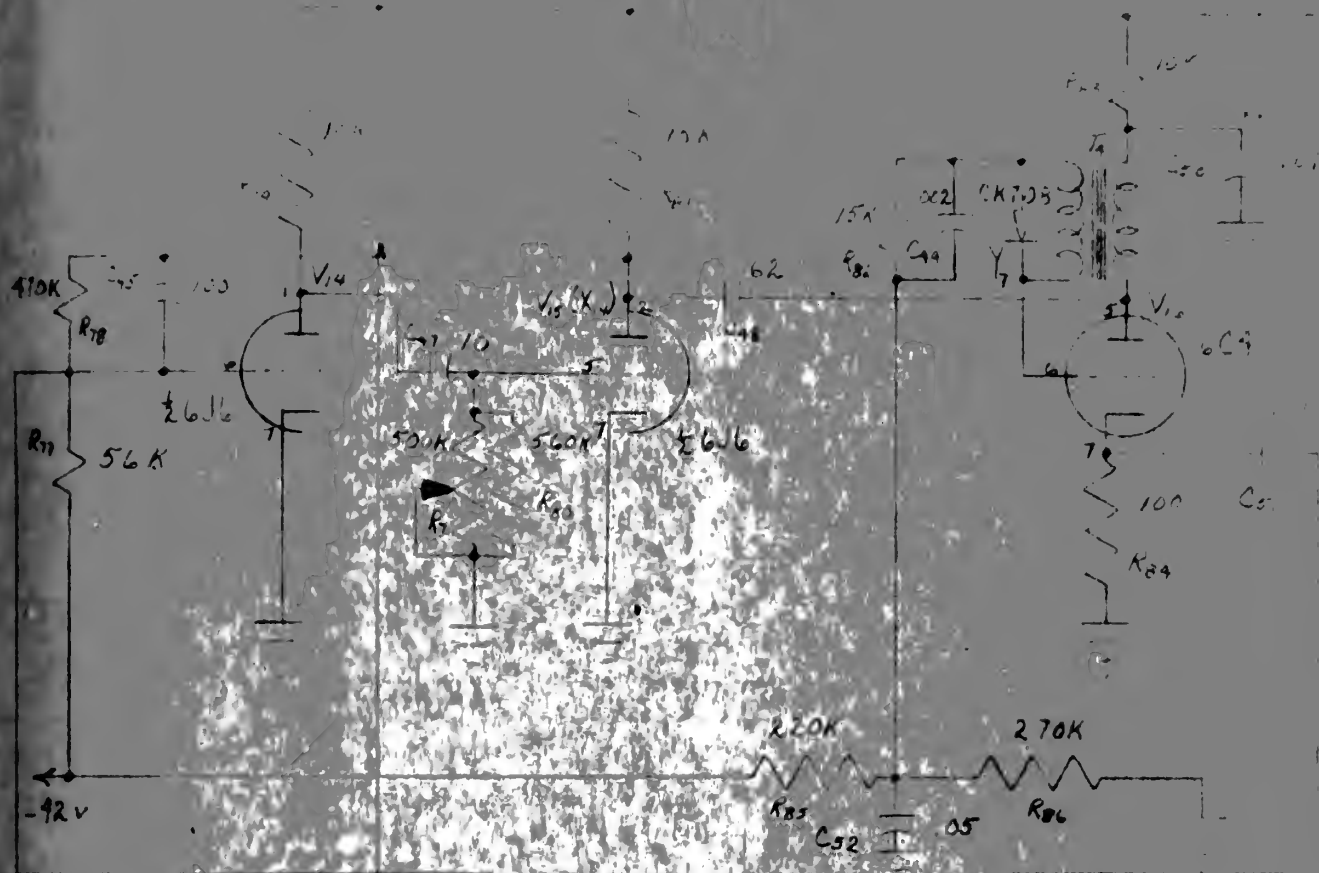
SCALE	TITLE	MELPAR, INC.	
DRAWN	Chas. A. (E) of M. J. J. J.	ALEXANDRIA, VA.	
APPROVED	MATERIAL	PROJECT NO	EA 4
DATE	FINISH	# 1153	



C_{23} is the shunt and stray capacitance across R_{58} to ground.

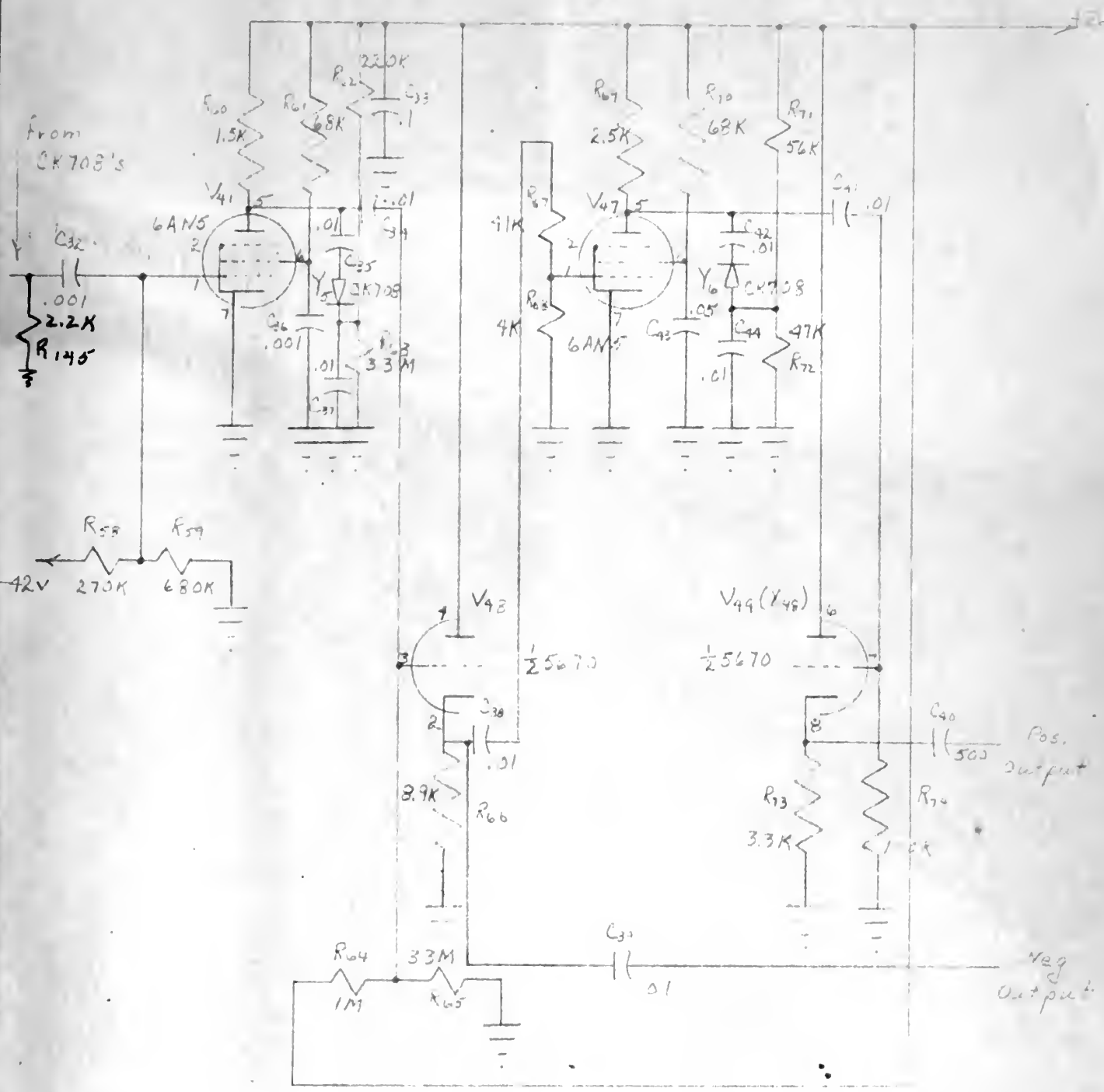
MAR 4 1952

SCALE	TITLE	MELPAR, INC.	
DRAWN	Channel (C) of Modulator	ALEXANDRIA, VA.	
APPROVED	MATERIAL	PROJECT NO	EA 5
DATE March 1952	FINISH	#1153	



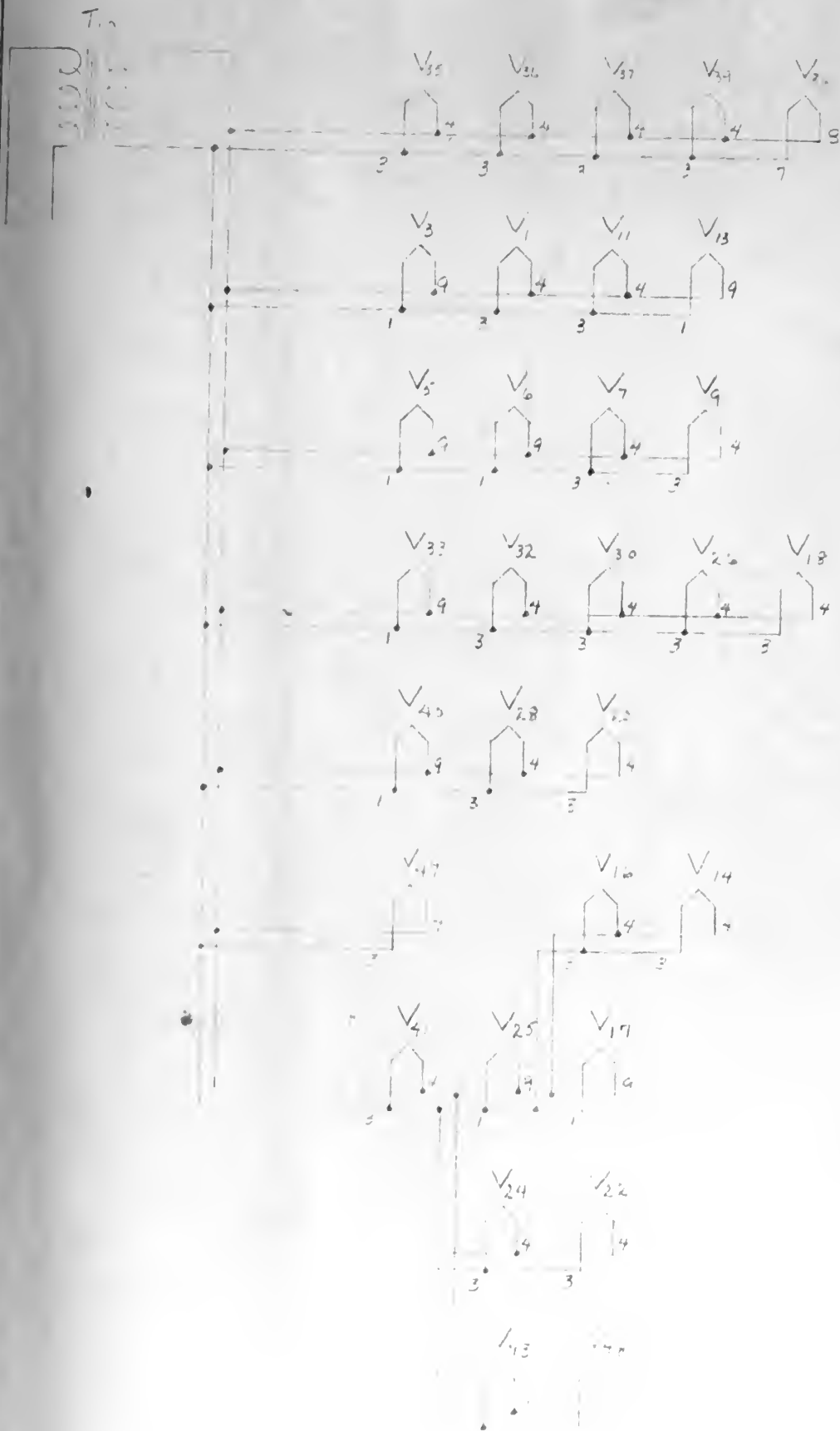
T₄: See data for T₁ on
dwg. EA3.

SCALE	TITLE	MELPAR, INC.	
DRAWN	Change (D) of Modulator	ALEXANDRIA, V.A.	
APPROVED	MATERIAL	PROJECT NO.	EA 6
DATE	FINISH	# 1153	



MAR 4 1952

SCALE	TITLE	MELPAR, INC.	
DRAWN	Part 1 of 2 - Missions	ALEXANDRIA, VA	
APPROVED	MATERIAL	PROJECT NO	EA 7
DATE	FINISH	11/15/52	



MAR 11 1952

SCALE	TITLE F	MELPAR, INC. ALEXANDRIA, VA	
DRAWN	MATERIAL	PRICE IN	EA 9
APPROVED	FINISH	4	
DATE 11/1/52			

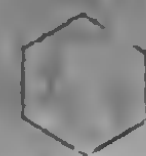
B

11
UN
SP

DECIMALS ±
FRACTIONS ±

COMMERCIAL PUBLISHED TOLERA
TO SIZES OF BAR ROD WIRE

CHANGE:



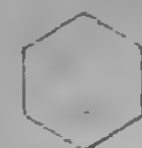
Reg.



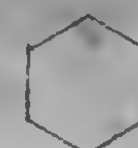
Fixed (B)



H (C)



Coarse



Fine



Rep (A)



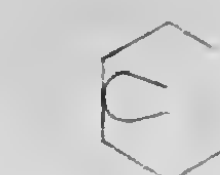
Sync. Out



Fix - Wob



Wob - Fix



Fix - Wob



Fix - Wob



Audio In



Chan. D.



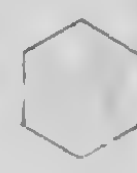
Chan. E.



Chan. F.



Chan. G.



Chan. H.



Fil.



H. V.



Pos. Out.



Pos. Out.

115V A-C.

UNLESS OTHERWISE
SPECIFIEDDECIMALS ±
FRACTIONS ±
COMMERCIAL PUBLISHED TOLERANCES SHALL APPLY
TO SIZES OF BAR, ROD, WIRE SHEET, TUBE, ETC.

7½" X 14"

CHANGE:

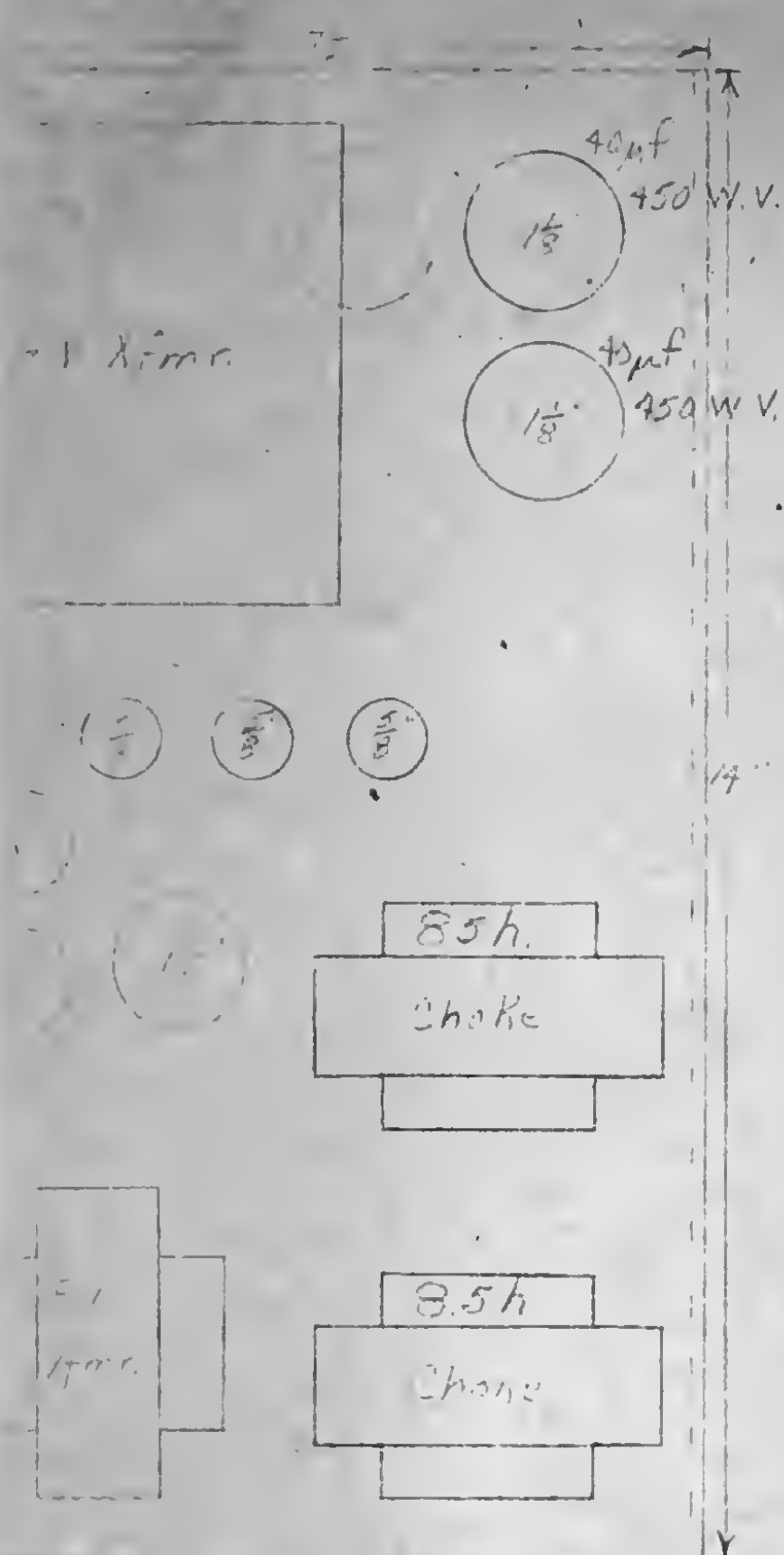
REQ'D	DRAWING		ITEM	NAME		FIN.	ZONE	CIRCUIT SYMBOL
	USED ON	ASSY. DRWG.	QTY.	MELPAR, INC. ELECTRONICS ALEXANDRIA, VIRGINIA				
				Front Panel of Modulator (actual size).				
				DRAWN BY <i>[Signature]</i>				
				ENGINEER				
				CHECKER				
				PROJ. ENGR.				
			APPROVED					
			SCALE					
			B					
			CHG.					

MAR 11 1964

B



DECIMALS ±
FRACTIONS ±
UNLESS OTHERWISE
SPECIFIED
COMMERCIAL PUBLISHED TOLERANCES SHALL APPLY
TO SIZES OF BAR, ROD, WIRE SHEET, TUBE, ETC.



Components shown are approx-
imate in size. Exact locations
not critical. Hole diameters
as shown.

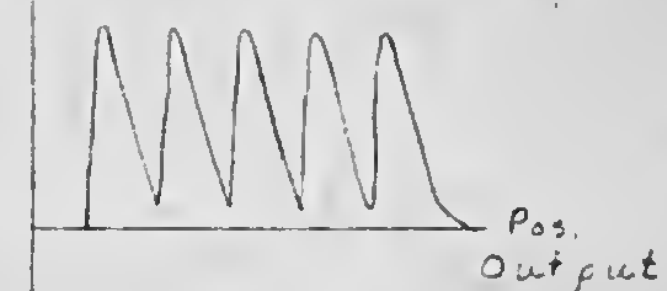
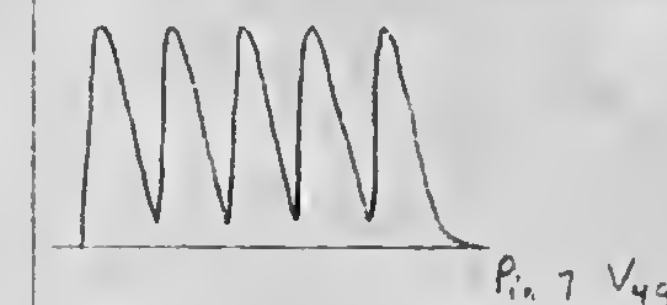
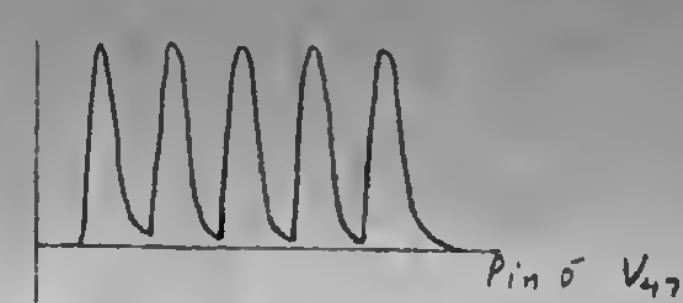
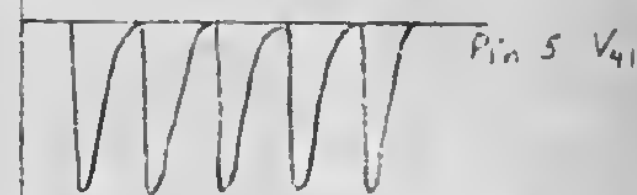
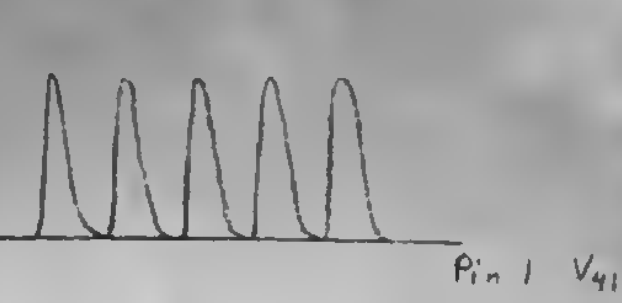
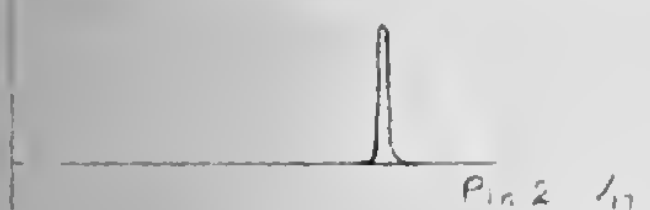
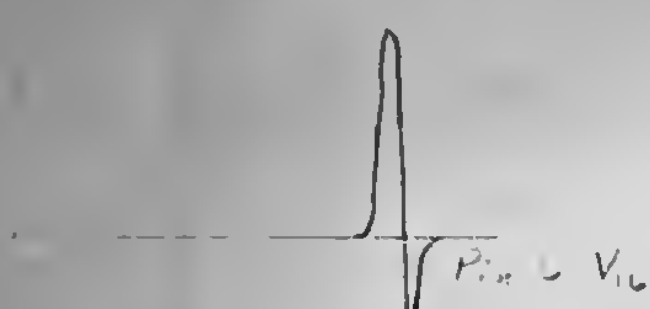
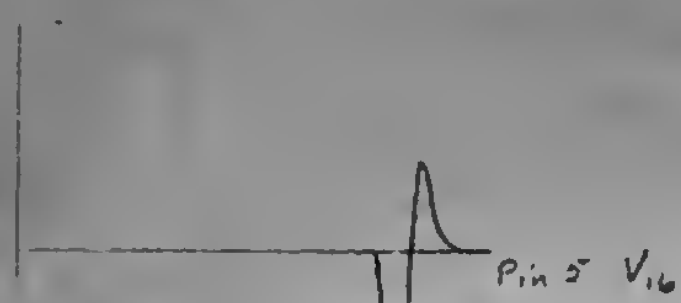
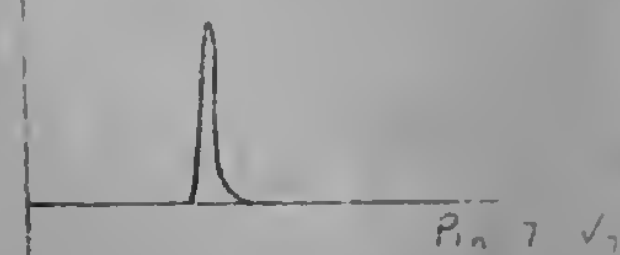
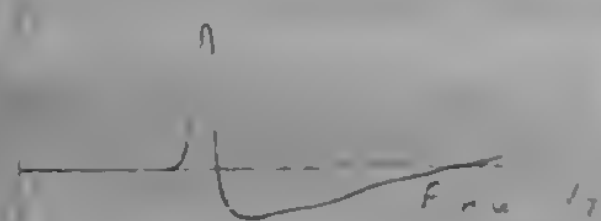
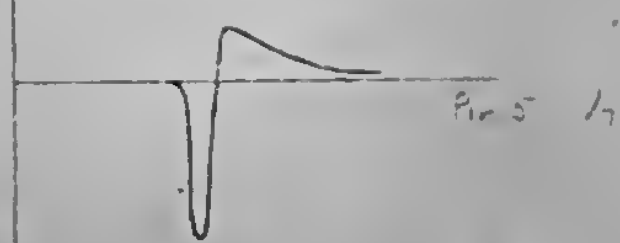
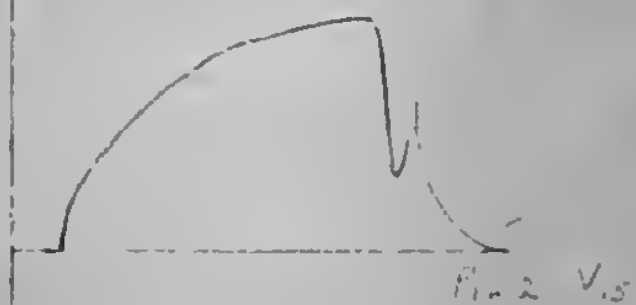
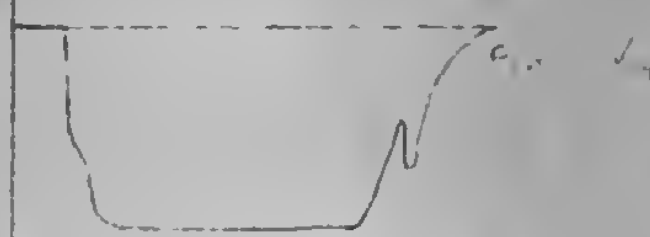
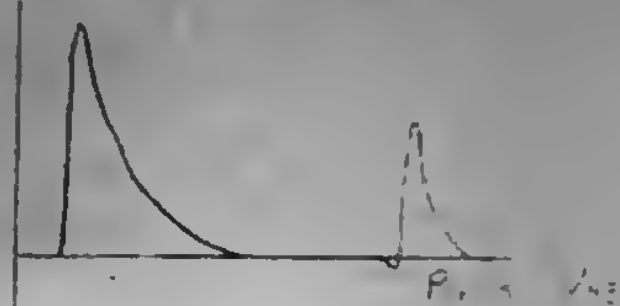
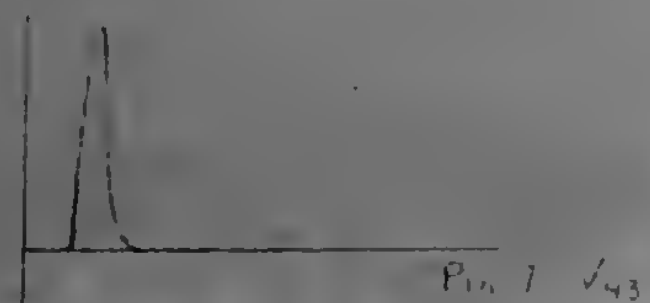
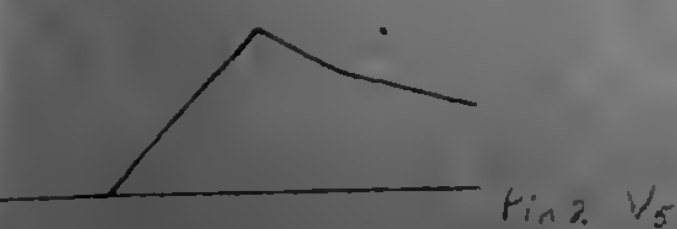
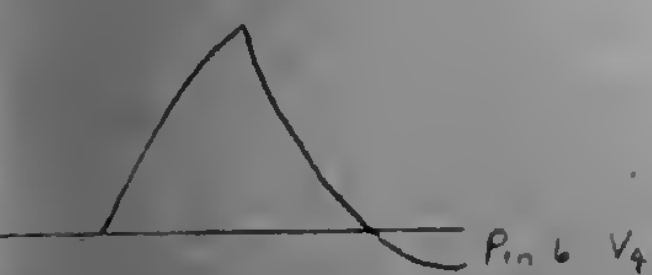
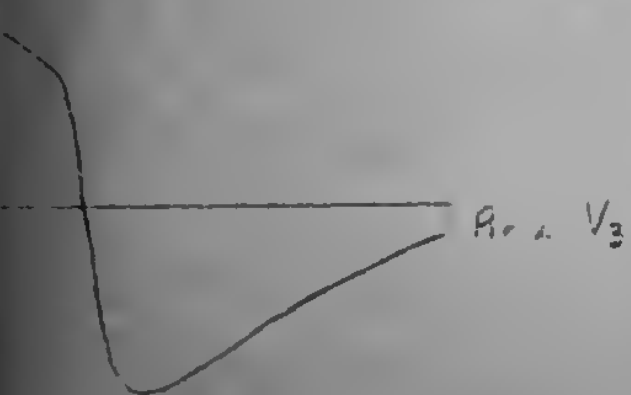
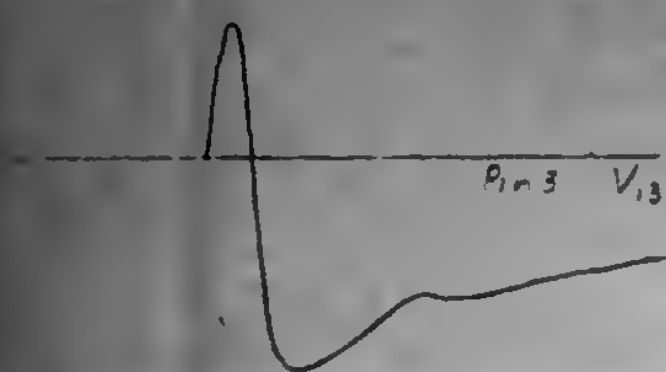
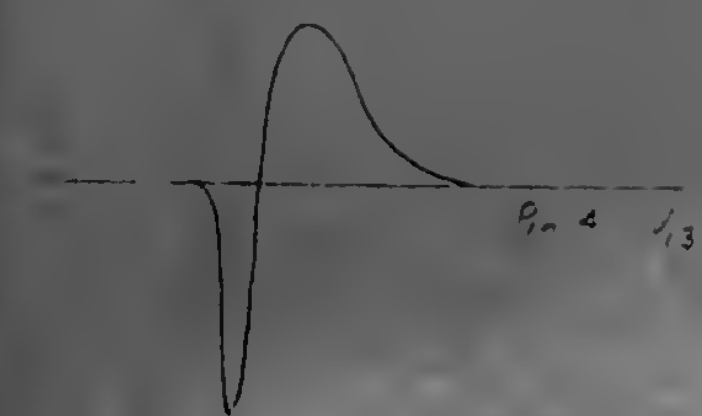
MAR 3 1952

REQ'D	DRAWING		ITEM	NAME		FIN.	ZONE	CIRCUIT SYMBOL	
	USED ON	ASSY. DRWG.		QTY.					
-1				MELPAR, INC. ELECTRONICS ALEXANDRIA, VIRGINIA					
				Plan View of Pulse Modulator Showing Component Space Allocations					
				DRAWN BY		ENGINEER		MATERIAL	
				CHECKER		PROJ. ENGR.		FINISH	
				APPROVED		SCALE		B	
						1/2			
B								CHG.	

CHANGE:



C



C

CHG

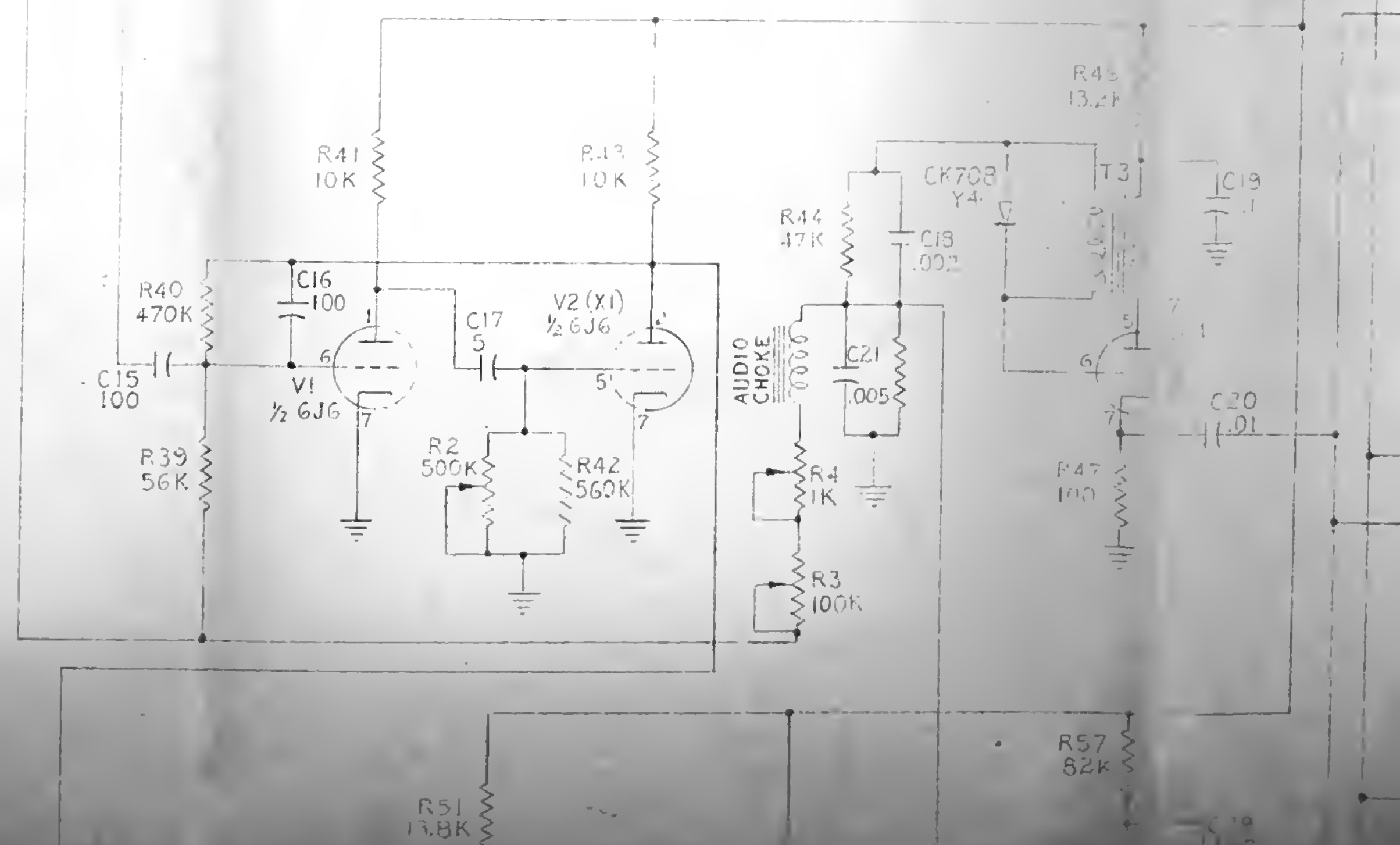
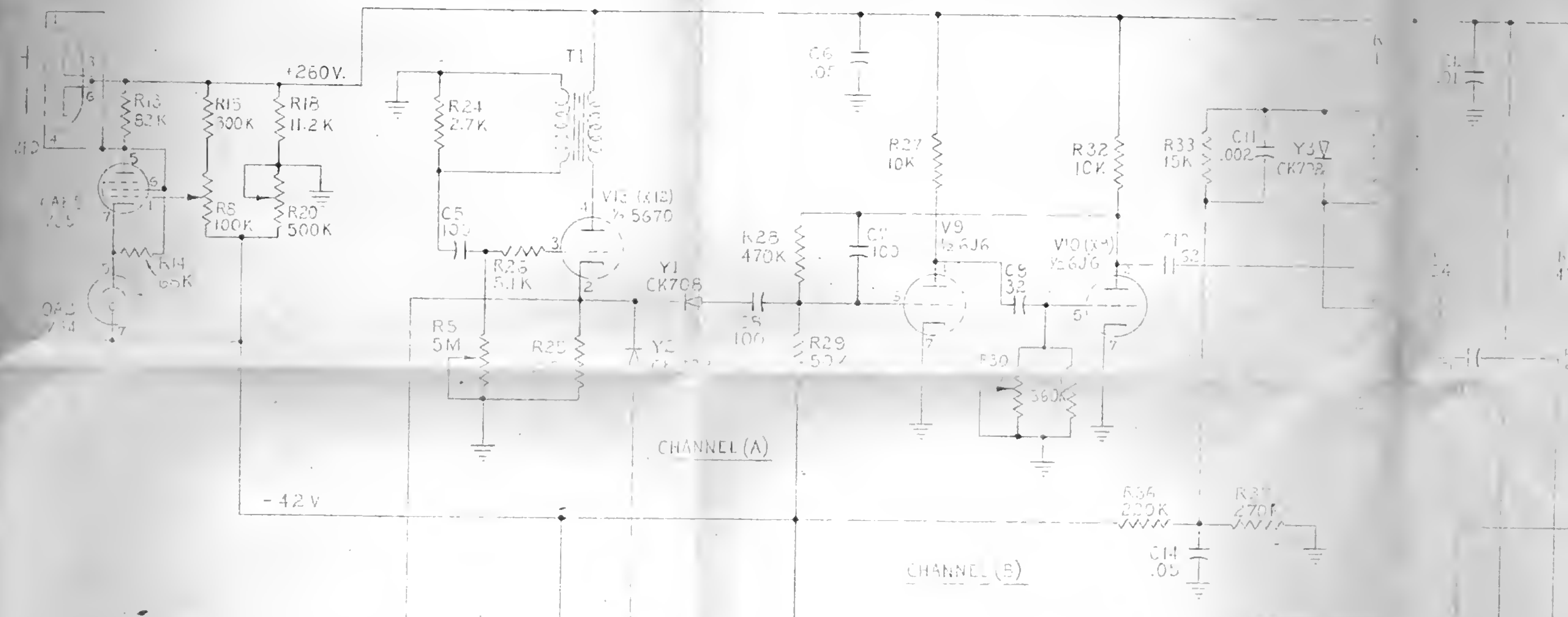
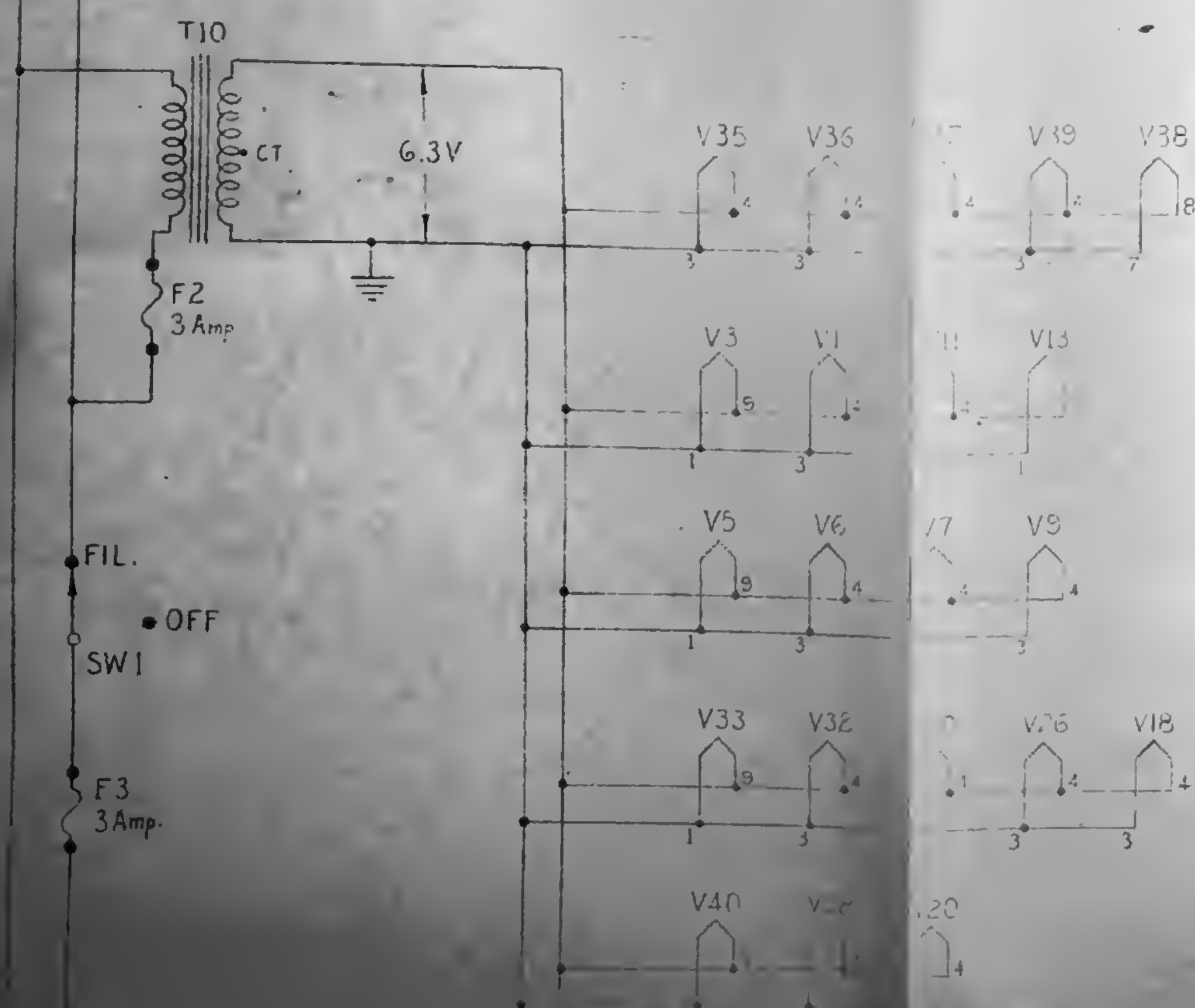
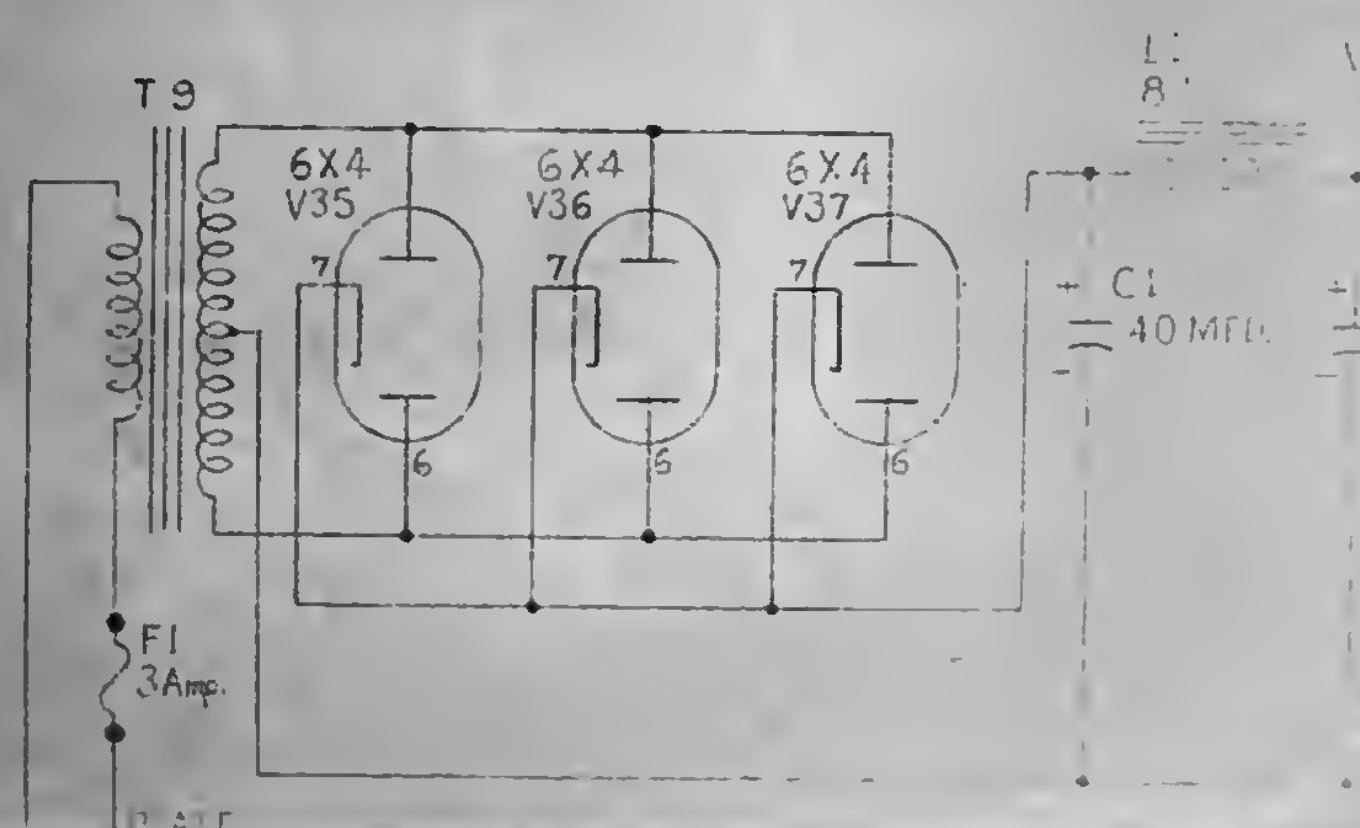
These waveforms are for reference for a quick check. For detailed waveforms showing amplitudes and time relationships, see waveforms for individual channels included elsewhere in this report.

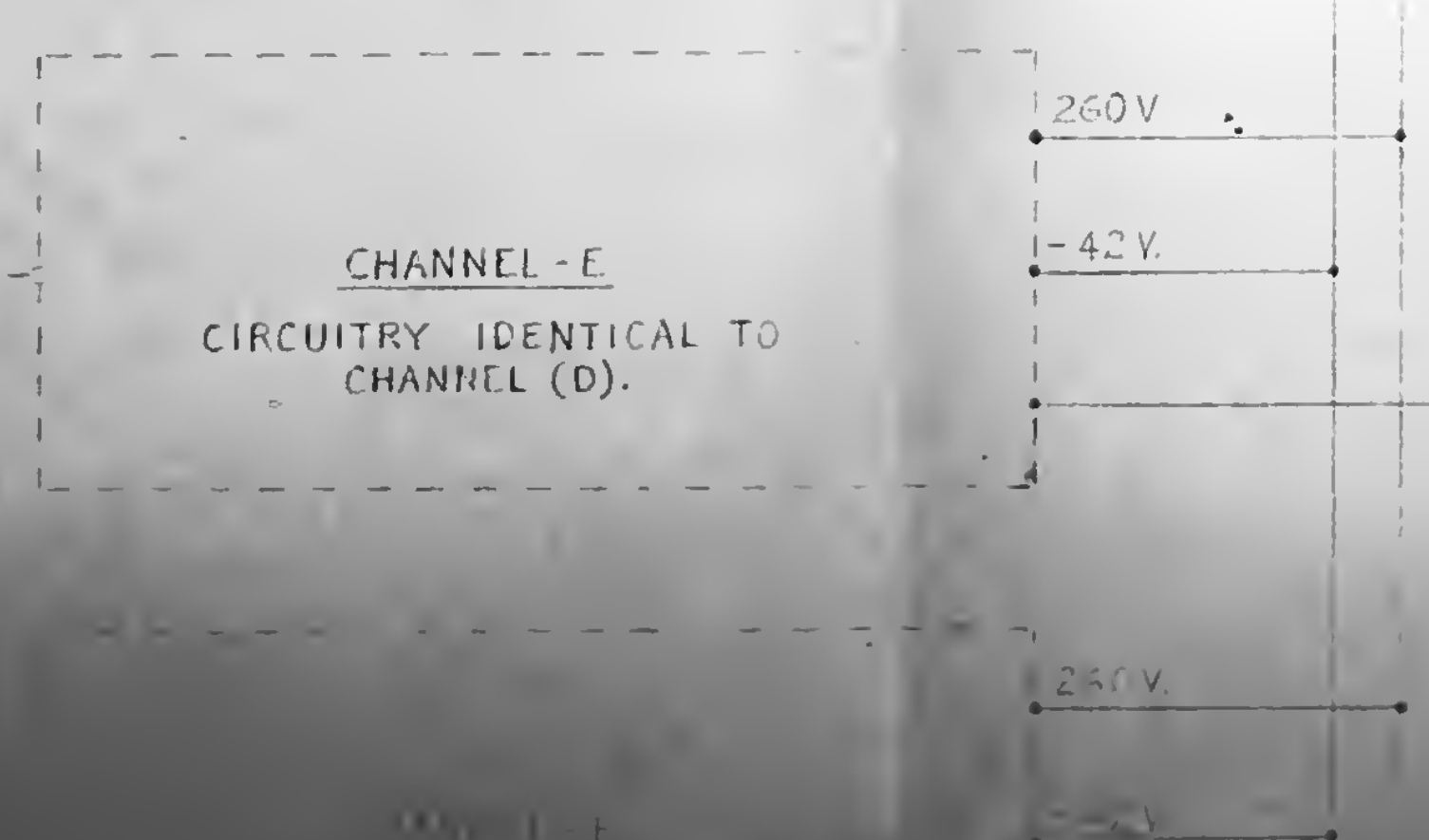
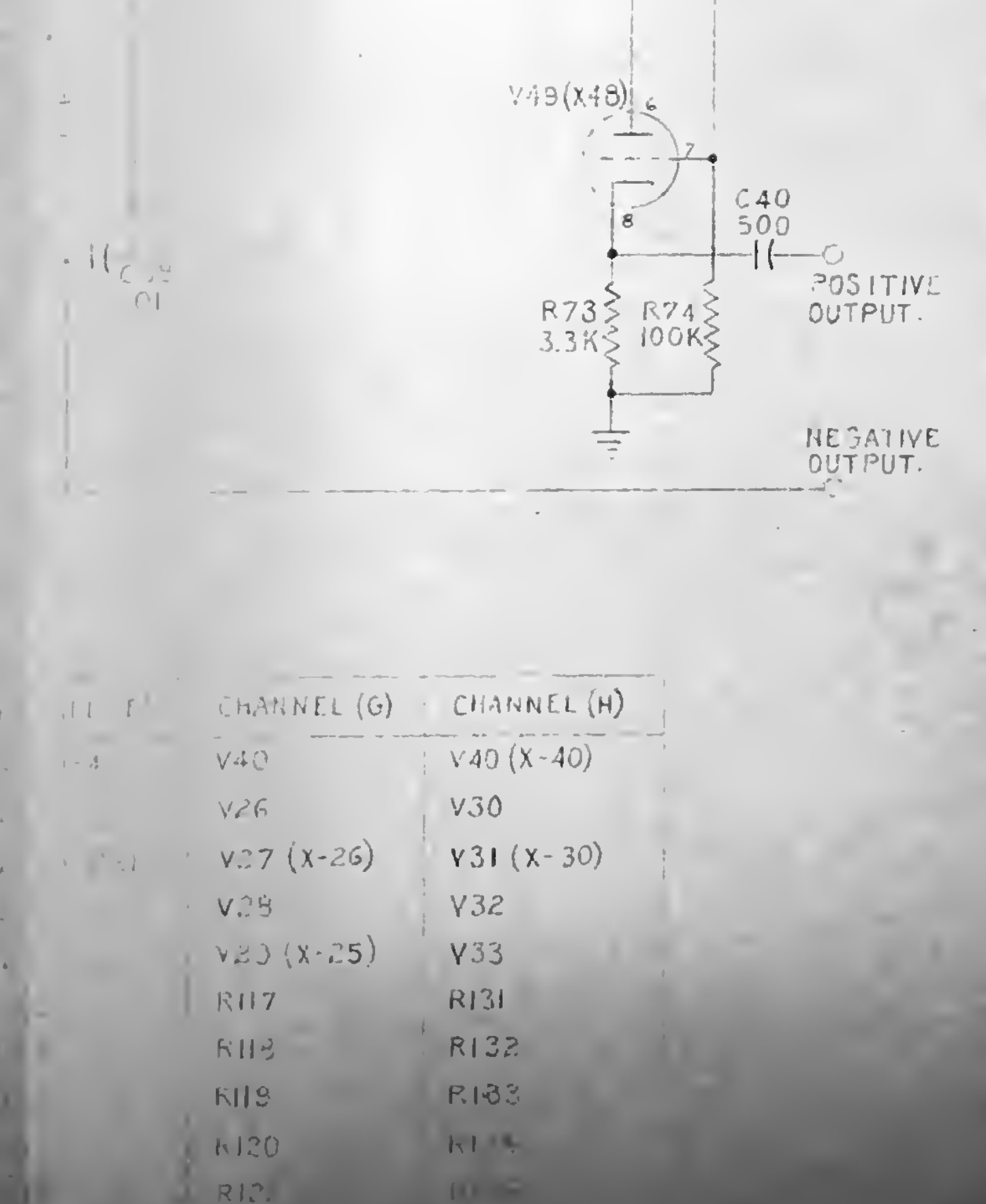
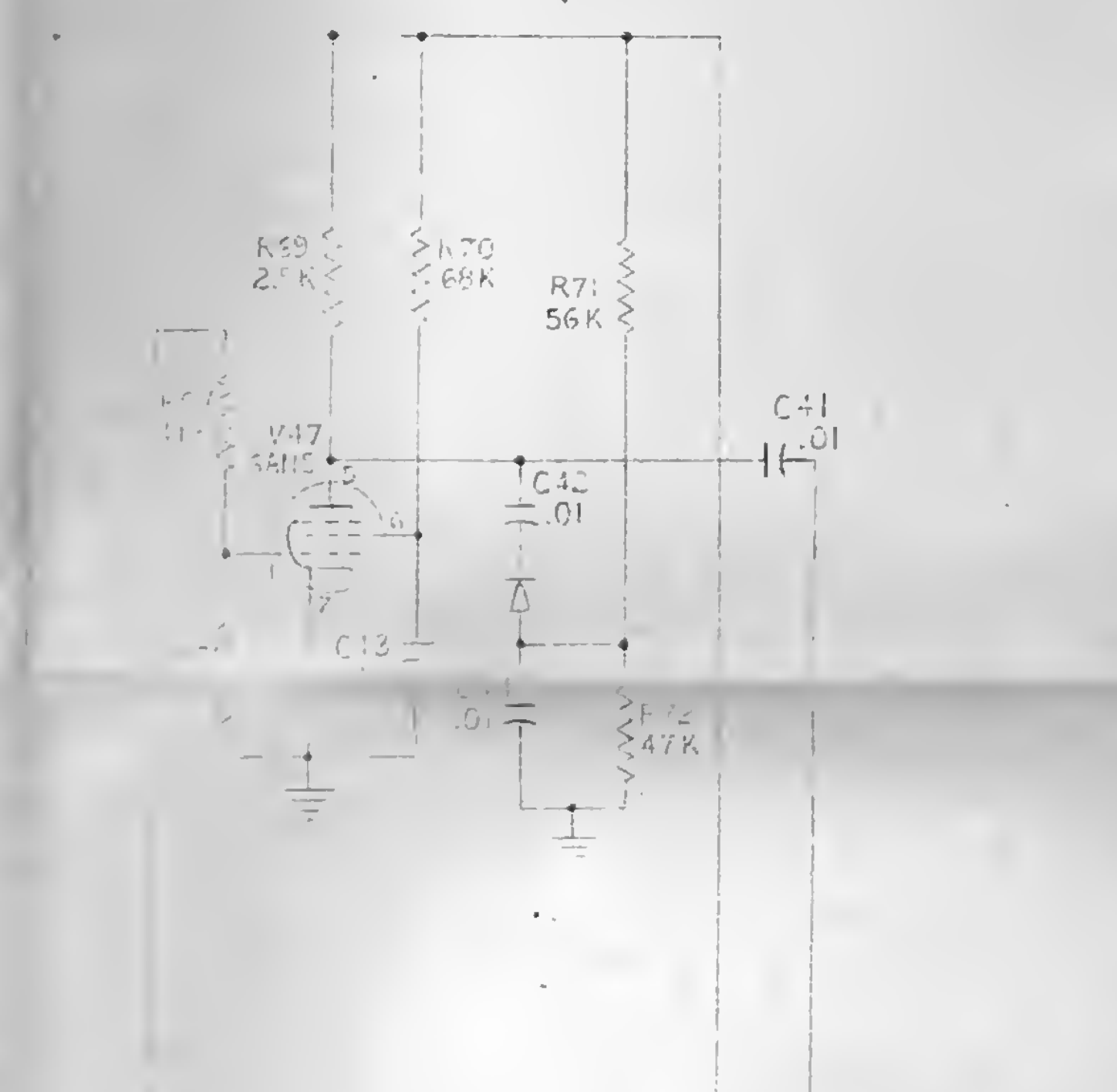
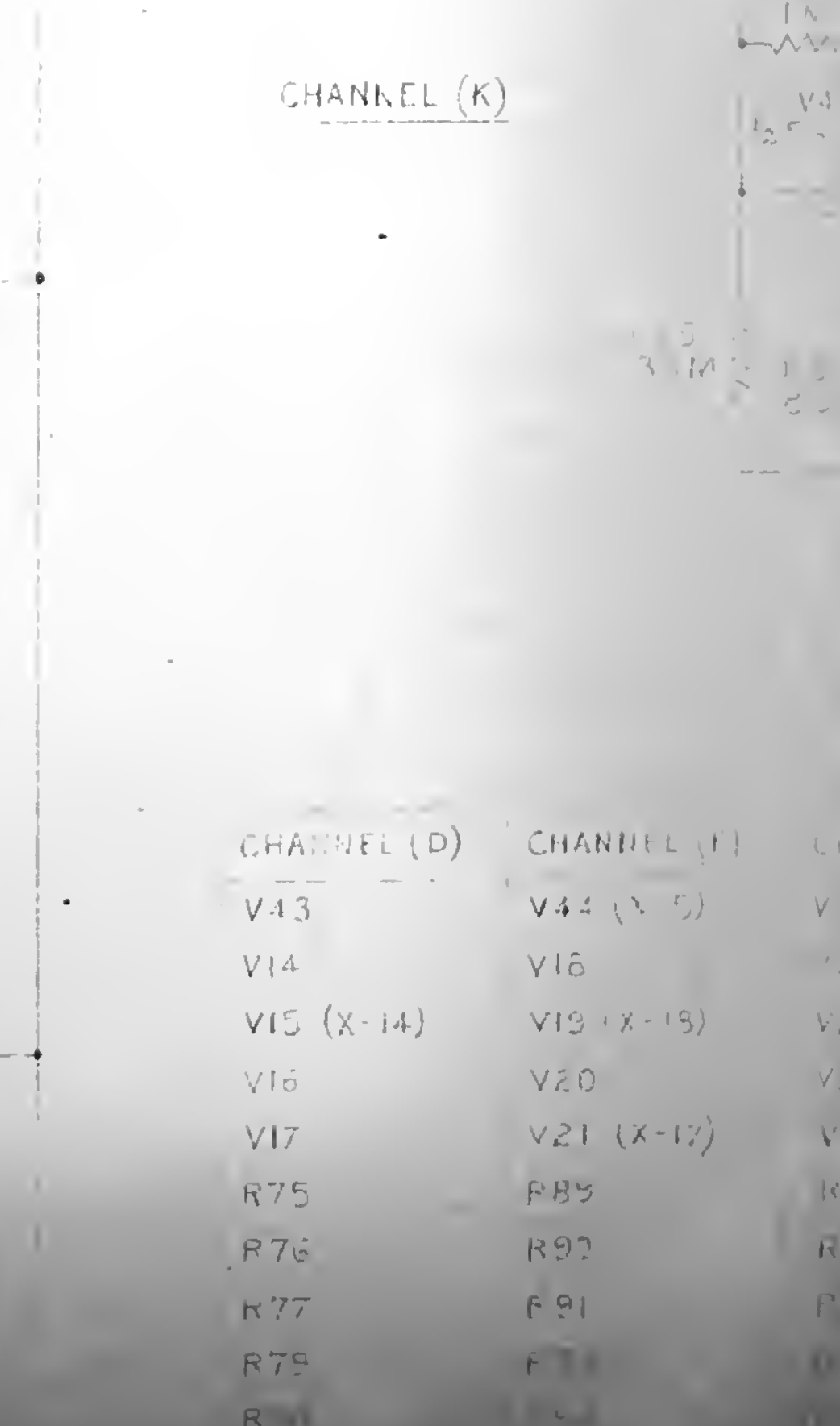
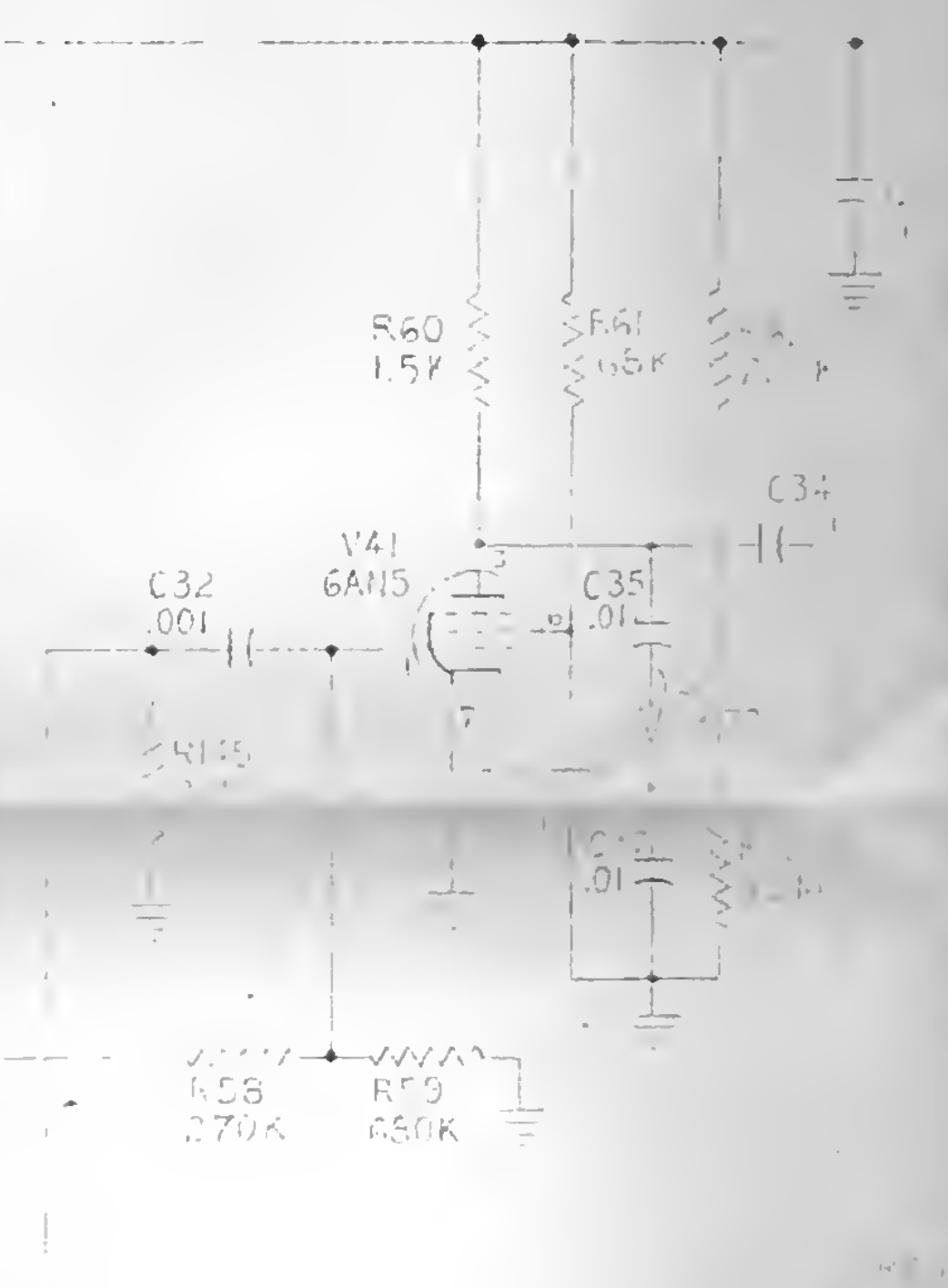
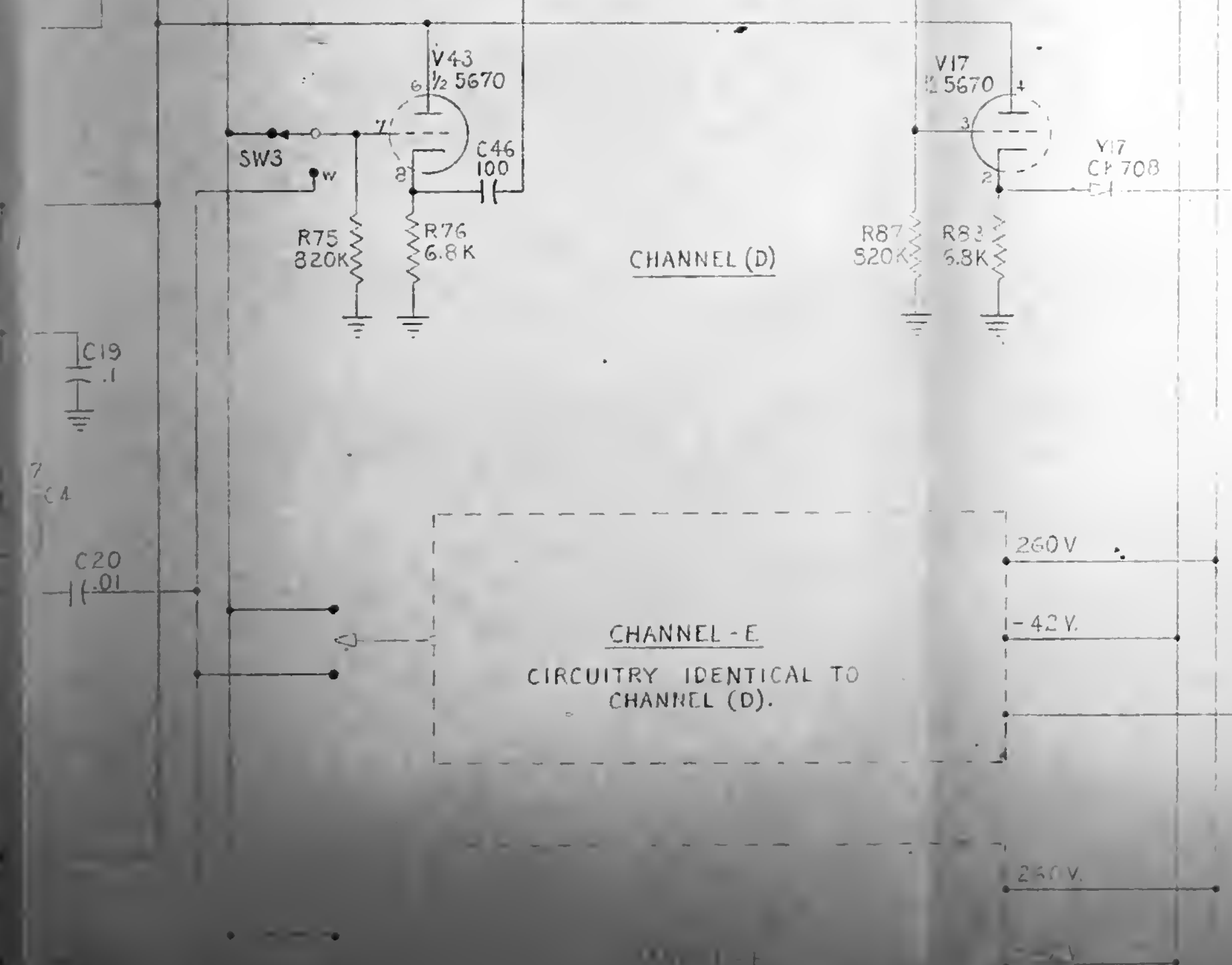
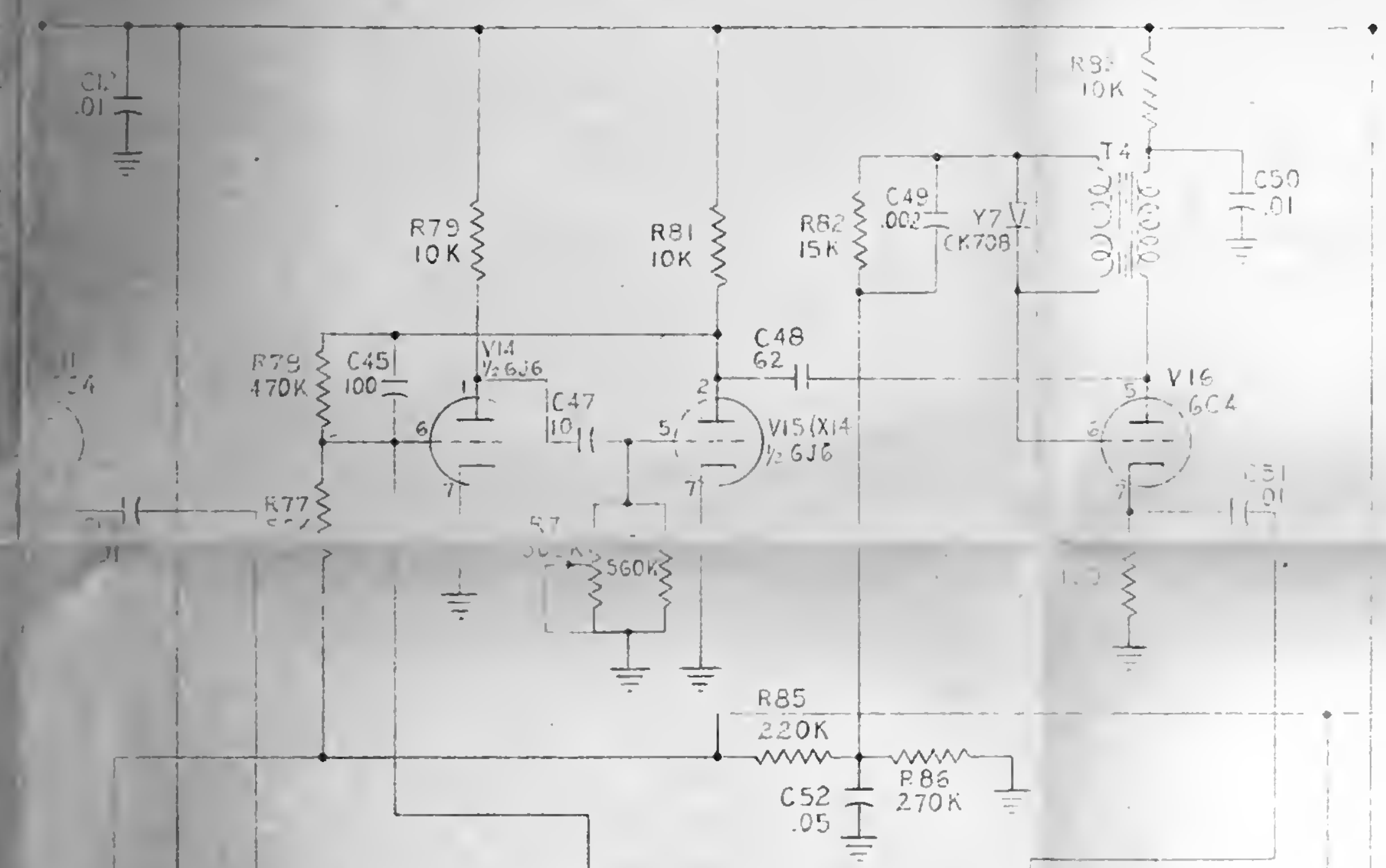
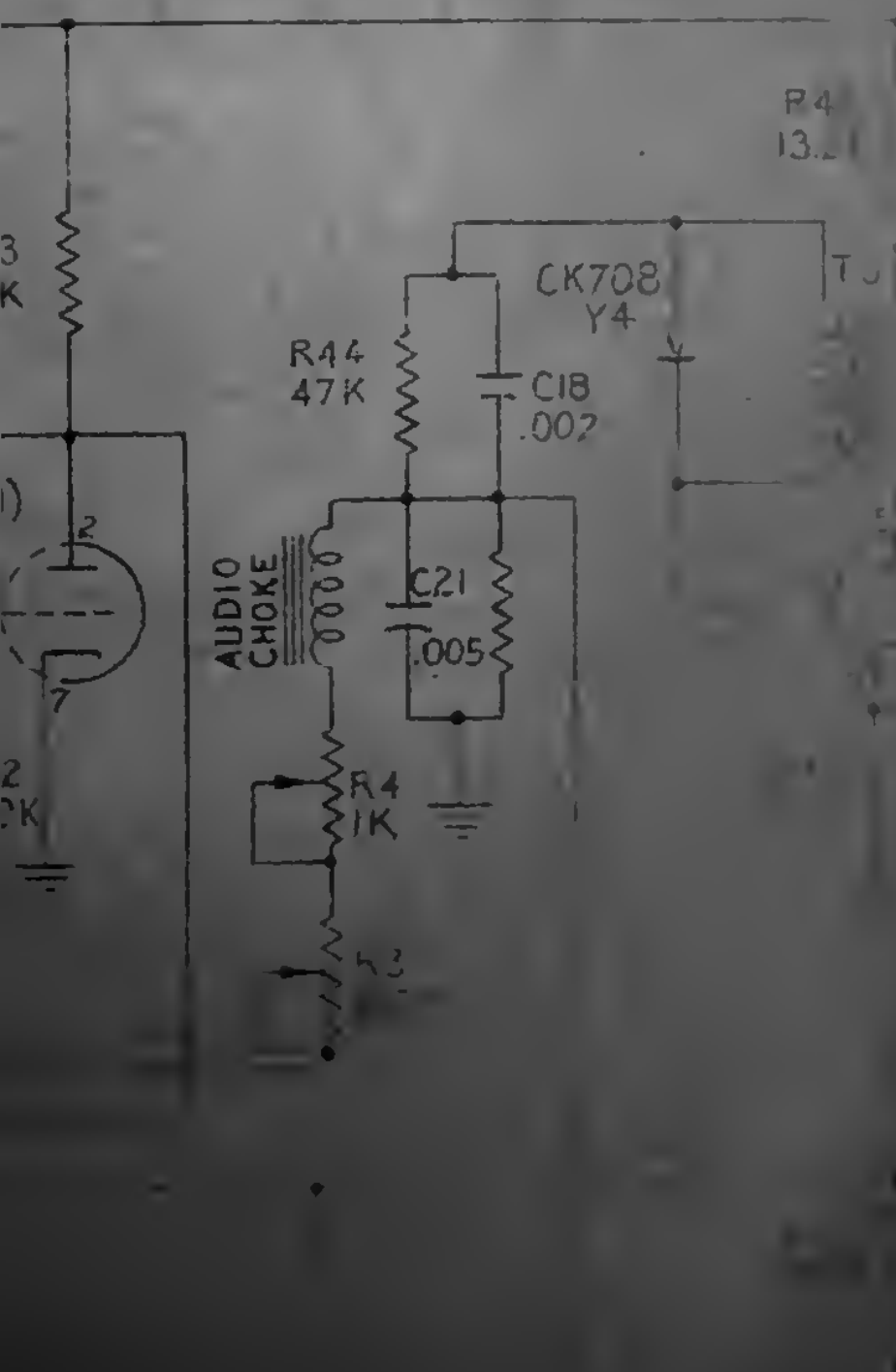
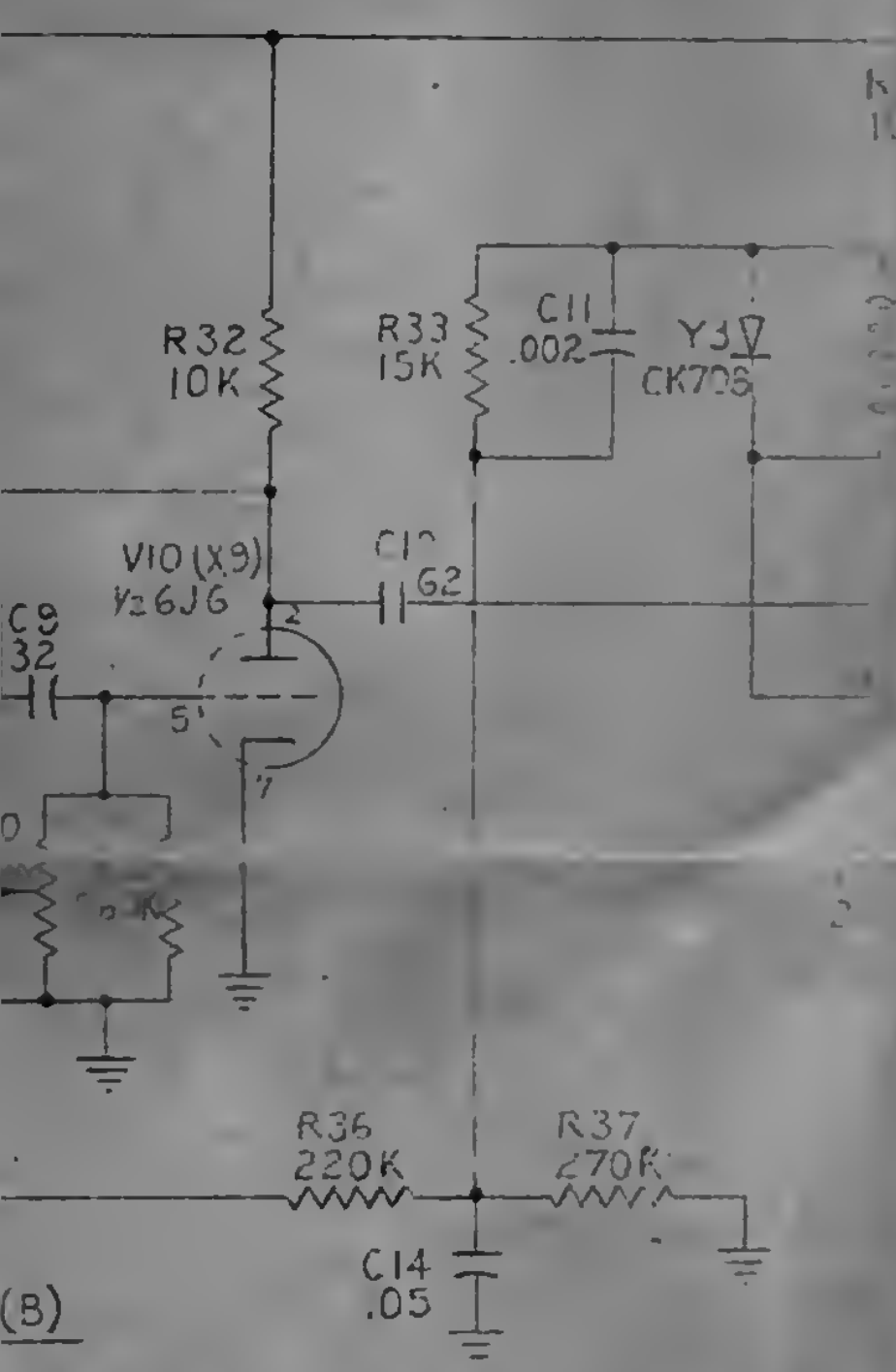
ANGULAR 2
DECIMALS 2
FRACTIONS 2
COMMERCIAL PUBLISHED TOLERANCES SHALL APPLY TO SIZES OF BAR, ROD, WIRE SHEET, TUBE, ETC.

CHANGE

REQ'D	DRAWING		ITEM	NAME	FIN.	ZONE	CIRCUIT SYMBOL
T	PROJECT NO.	NEXT ASSY	QTY.	MELPAR, INC. ELECTRONICS ALEXANDRIA, VIRGINIA			
U				Modulator Waveforms.			
DRAWING				DRAWN BY	ENGINEER	MATERIAL	
SIZE				CHECKER	PROJ. ENGR.	FINISH	
				APPROVED	SCALE	C	
						CHG.	

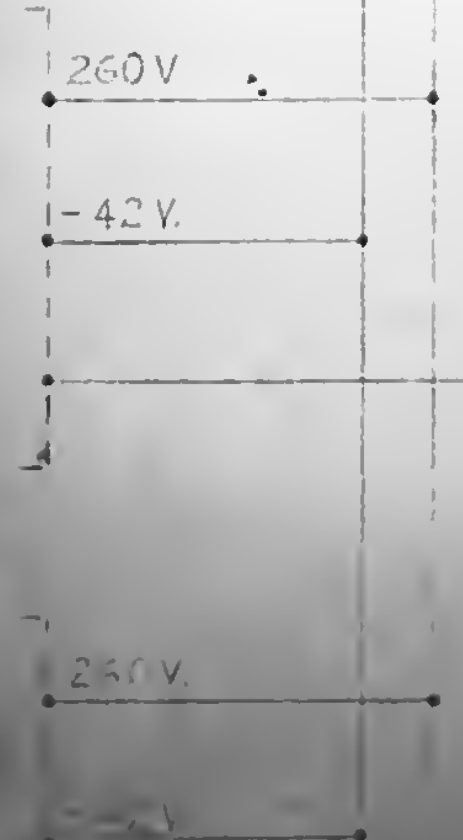
CONFIDENTIAL
SECURITY INFORMATION

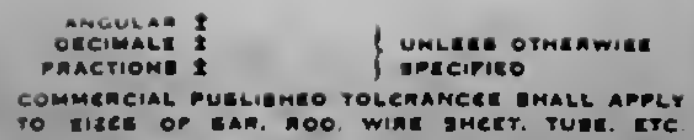


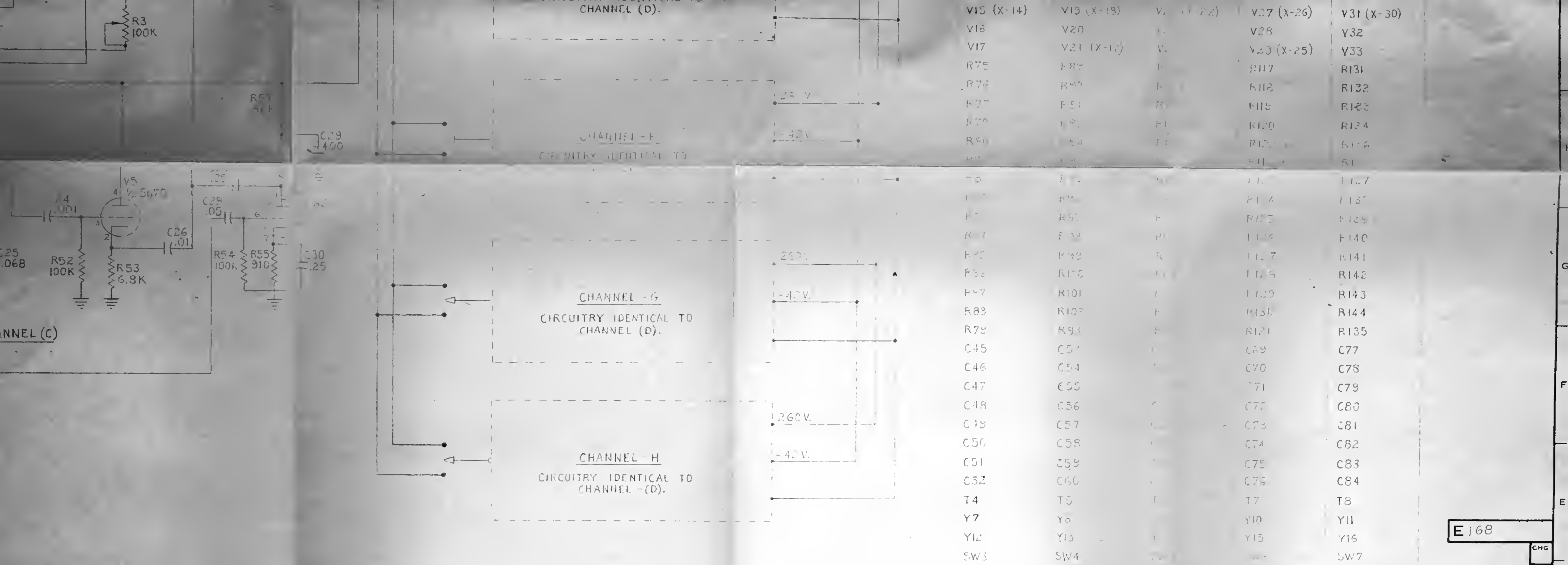


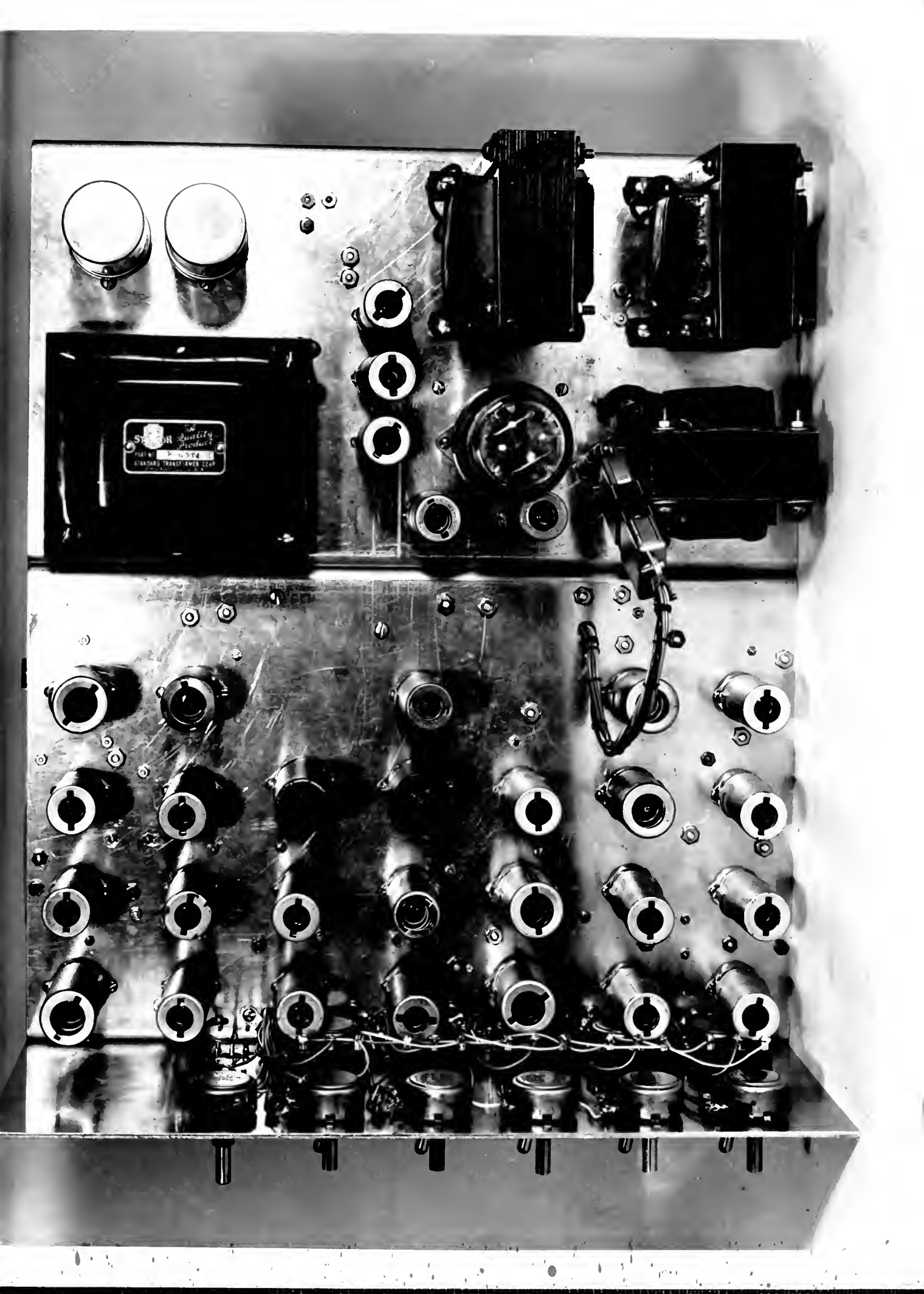
CHANNEL (D)	CHANNEL (F)	CHANNEL (G)	CHANNEL (H)
V43	V44 (X-5)	V40	V40 (X-40)
V14	V16	V26	V30
V15 (X-14)	V19 (X-13)	V27 (X-26)	V31 (X-30)
V16	V20	V28	V32
V17	V21 (X-17)	V29 (X-25)	V33
R75	R89	R117	R131
R76	R90	R118	R132
R77	R91	R119	R133
R79	R92	R120	R134
R81	R93	R121	R135

CHANNEL - E
CIRCUITRY IDENTICAL TO
CHANNEL (D).

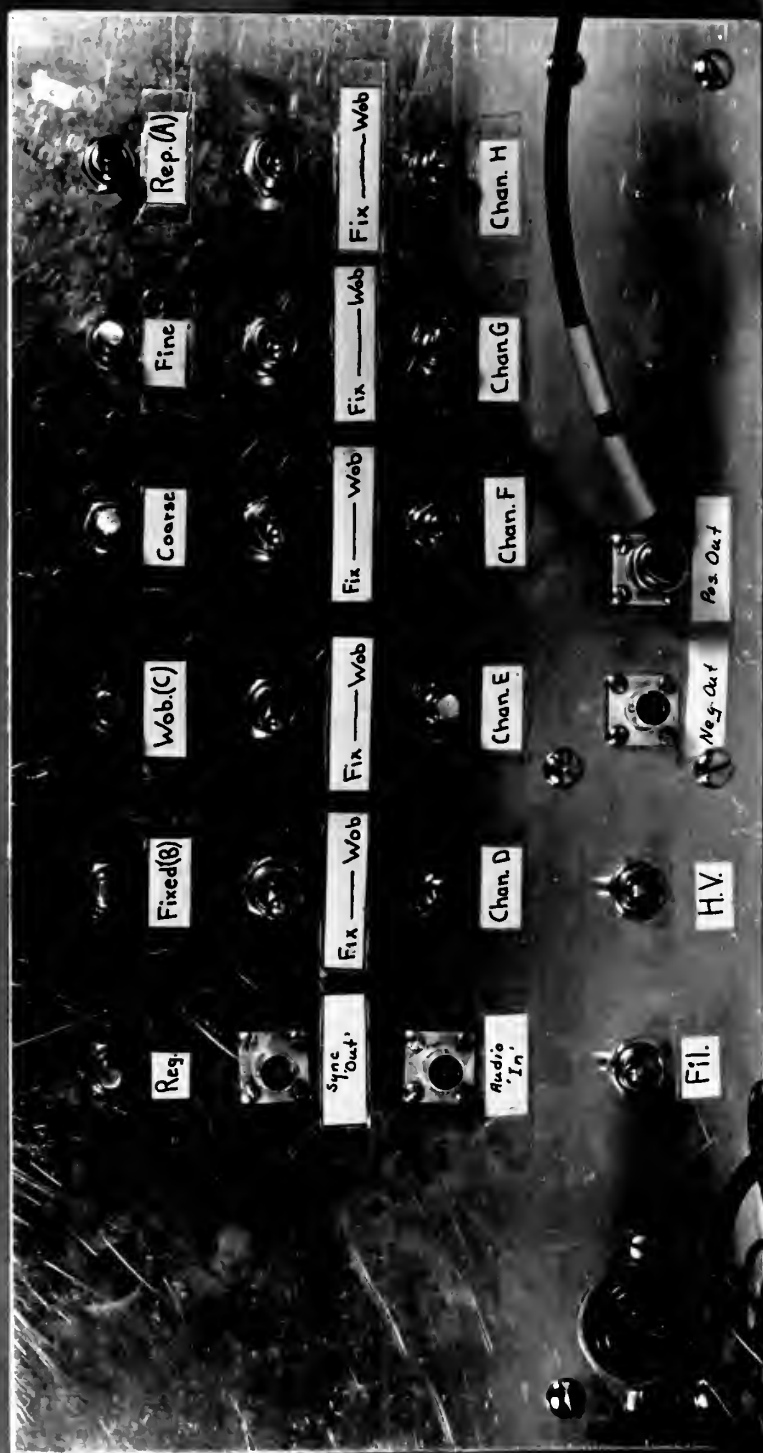




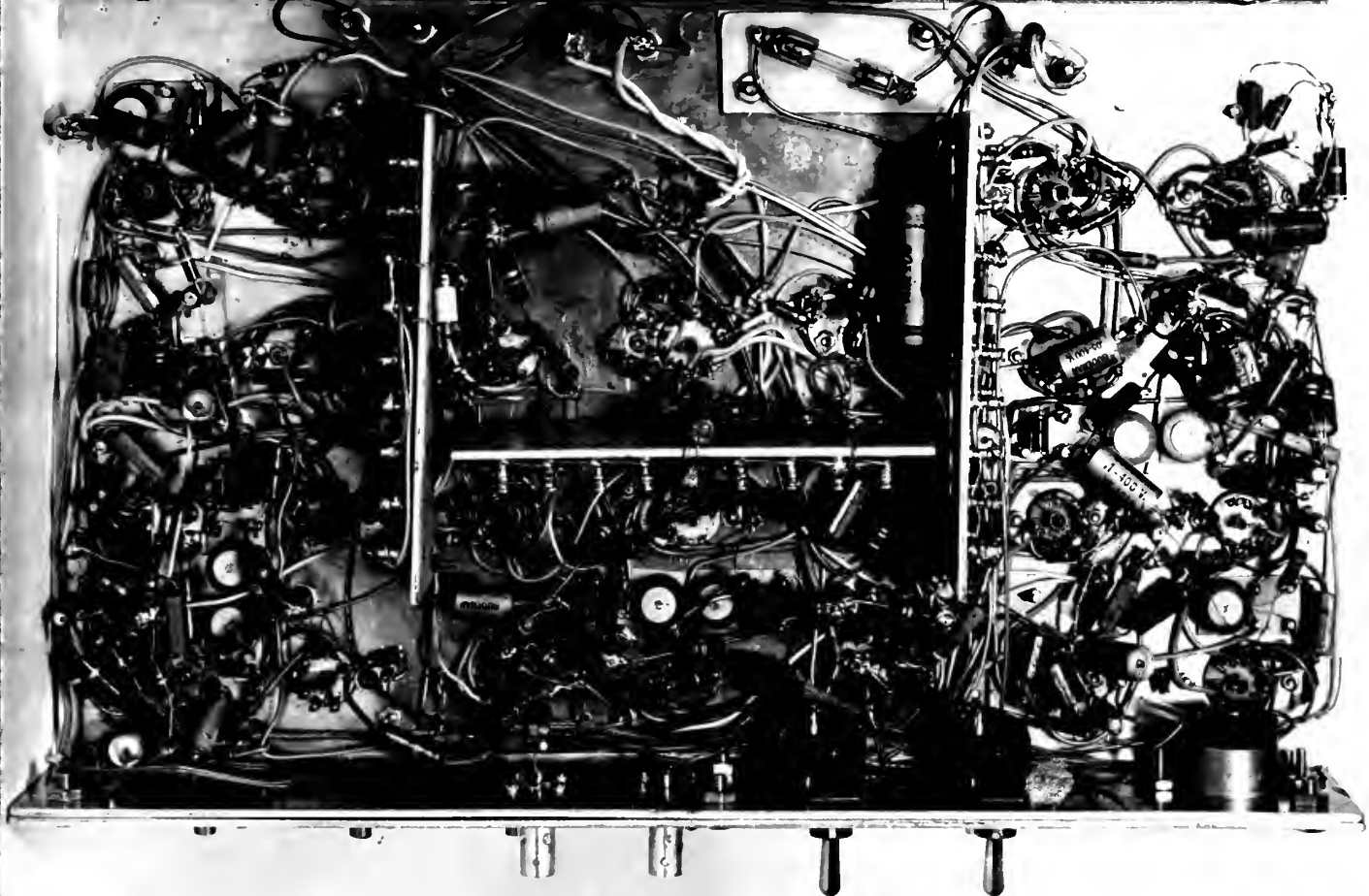
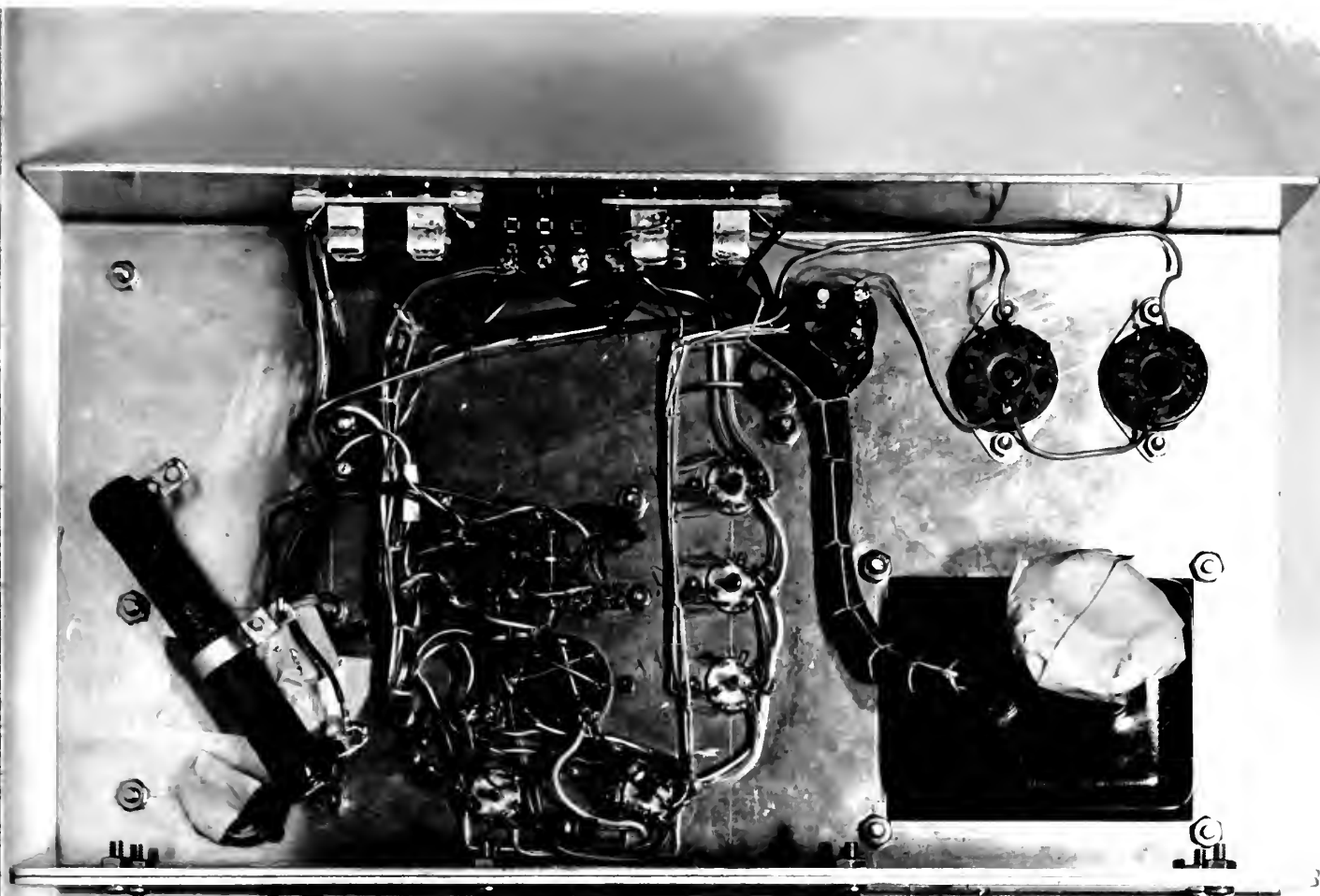


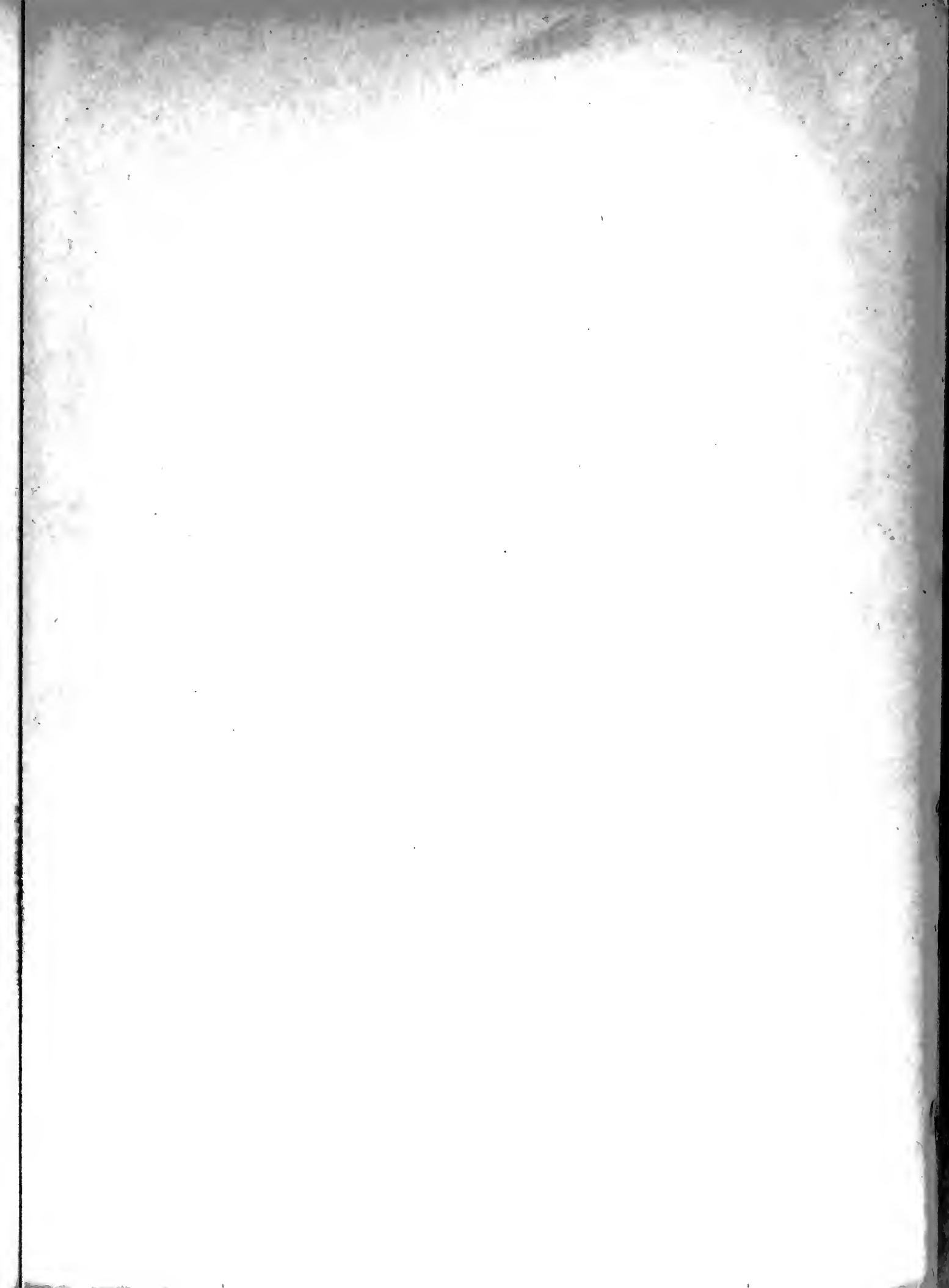


1153-3



1153-2





17 JUL 68

16547

R373

Rhine with 25028
multiple micro-
pulse generator.

17 JUL 68

16547

R373

Rhine with 25028
multiple micro-
pulse generator.

thesR373

A multiple micro-pulse generator.



3 2768 002 01338 5

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